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Human factors analysis of marine accidents based on HFACS by NVivo

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HUMAN FACTORS ANALYSIS OF MARINE ACCIDENTS BASED ON HFACS BY NVIVO

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Declaration

I certify that all the material in this research paper that is not my own work has been identified, and that no materials are included for which a degree has previously been conferred on me.

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the University.

(Signature):
(Date): 2020.06.20

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Abstract

Title of Dissertation: **Human Factors Analysis of Marine Accidents Based on HFACS by NVivo**

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Maritime accidents often lead to serious economic losses, casualties, and unpredictable environmental pollution losses. Research has confirmed that more than 90% of accidents are related to human factors，which is one of the main causes of marine accidents. The purpose of this paper is to review the literature, then a certain number of accident reports will be analyzed for text mining, and then we will draw relevant conclusions through qualitative analysis.

Human Factor Analysis Classification System (HFACS) is very practical and has been used in accident analysis in aviation, coal mining and other industries. In order to better study the maritime accident, this paper summarizes the contents of each element through the literature research method, combined with the maritime accident HFACS model framework, and provides a basis for using the model to analyze accident reports from various databases. Then based on the maritime accident HFACS model framework, the qualitative analysis software NVivo was used for statistical analysis of 330 maritime accident reports, and the number of causative factors at all levels of the framework was obtained. Finally, this paper summarizes the results of NVivo analysis and the impact of the upper layer on the lower layer of the maritime accident HFACS model framework and puts forward some suggestions for the prevention of maritime accidents.

KEYWORDS: Maritime accident, Accident analysis, HFACS, NVivo

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LIST OF ABBREVIATIONS

ATSB	Australian Transport Safety Bureau
HFACS	Human Factor Analysis Classification System
MAIB	Marine Accident Investigation BranchMarine
RORO	Roll-on Roll-off
TAIC	Transport Accident Investigation Commission New Zealand
TSB	Transportation Safety Board of Canada

Chapter 1 Introduction

1.1 Research Background

Accidents at sea often lead to serious economic losses, casualties, and unpredictable environmental pollution losses. In order to avoid the occurrence of maritime accidents, it is particularly important to study the causes. Rothblum (2000), based on an analysis of the US Coast Guard report, pointed out that approximately 75% to 96% of marine casualties are at least partially caused by some form of human error. Tzannatos (2010) investigated the Greek marine accidents that occurred between 1993 and 2006 and found that human factors accounted for 57.1% of the investigations. According to the statistics of the British P&I Association (1997, 2004, 2005), more than 53% of the maritime and port accidents in recent years were caused by human error, of which 21%, 16%, 11%, 4% and 2% are errors of deck personnel, crew members, shore personnel, pilots and engineering personnel. The unsafe acts of the crew, as well as physical, psychological, medical, workplace and environmental factors, obviously led to such accidents. Other studies and reports also indicate that 60% to 90% of maritime accidents can be attributed to "human factors" (Zohar, 1980; Sherry, 1991; Mars, 1996).

At present, the research on the causes of accidents has shifted from individuals to organizations. The HFACS model initially analyzes human errors in the aviation field and explores the individual factors, working conditions, team factors and organizational factors of accidents in this field. It has a positive impact on accident prevention. The model has been tried and applied in the fields of navigation, mining, railways, etc., all of which are practical and reliable.

There are many reasons for maritime accidents, including environmental and mechanical reasons such as weather and driving equipment, as well as human factors such as misjudgment of collision avoidance and illegal operations, as well as daily management reasons. Among them, human reasons should dominate, because whether it is daily management, mechanical operation or environmental conditions judgment, all are carried out by people, and the quality of people varies, and the handover between people may be affected, resulting in wrong behavior. On the other hand, according to behavioral and psychological research, human behavior will be affected by the surrounding environment and personal psychological factors, which may lead to violations and errors in work. Therefore, it is of great significance to study the human factors of maritime accidents.

This study focuses on the analysis of human factors in maritime accidents, categorizes and elaborate the human factors in maritime accidents, thoroughly analyzes the human factors that caused the accidents, and gives targeted measures in order to put forward certain suggestions for maritime safety management, which allows maritime accidents to be greatly reduced while minimizing damage to the environment and personnel. In this study, through in-depth analysis of the human factors of maritime accidents, it can promote the safety management of maritime navigation, and at the same time, it can promote the improvement of the crews' safety awareness, so that they realize that their daily work behaviors will play an important role in international maritime transportation. In the meantime, people's understanding of human errors can help to formulate safety management systems.

1.2 Literature Review

Human factors have always been a major issue in the study of marine accidents. People have never stopped researching in this area. Research on this topic can be traced back to the late 1980s.

Gordon (1988) used data mining methods to study how human factors caused Oil spill accidents. After collecting 25 types of accident report forms for offshore oil companies in the North Sea UK, the author manually identified various types of human factors in the accident reports and roughly classified them, and finally put forward suggestions on how to improve these accident report forms. Helfrich (1999) used data mining methods to research the reliability of researchers from a technical perspective (from the perspective of probabilistic models) or an overall psychological perspective using information processing or decision-making models. After the author re-identified and analyzed human factors in 100 marine accidents manually, research shows that there are serious flaws in focusing on individuals or a collection of individuals. Statistical analysis shows that individual contributions are not independent. Instead, they seem to be influenced by the social interactions reflected in the two's cases.

Ten years later, people's research on the subject shifted from individual to organization.

Celika and Cebi (2009) used the method of data mining to propose an analytic human factor analysis and classification system (HFACS) based on the fuzzy analytic hierarchy process (FAHP) to identify the role of human error in transportation accidents. The author performed manual human identification of the collected accident reports and categorized these factors into the broad structure of HFACS, including four main levels of investigation programs, which are classified into the following categories: unsafe behaviours, prerequisites for unsafe behaviours, unsafe surveillance and organizational impact.

Chauvin et al. (2013) used data mining methods and introduced a modified version of the human factor analysis and classification system. The data manually extracted and analyzed by the author from the MAIB and TSB reports shows that most conflicts are caused by decision errors.

Akyuz and Celik (2014) combined the human factor analysis and classification system (HFACS) with the cognitive map (CM) to manually identify human factors and determine the positive and negative relationships between human factors for marine accident analysis. The HFACS-CM model is considered as a hybrid accident analysis method. It provides the distribution of human error by considering operational evidence. The data comes from MAIB. The results show that the HFACS-CM method is operational in practice and can help identify and reduce human accidents.

Akhtar and Utne (2014) used a mathematical model to introduce a general method for developing Bayesian networks (BN) to model the risk of maritime ship accidents. The data were derived from 93 accident investigation reports. The BN model shows that fatigue has a significant impact on the possibility of grounding. Operator exhaustion has increased the likelihood of large ships being grounded for long-distance transport by 23%.

Sandhaland et al. (2015) studied the accident of the ship collision, using descriptive analysis research methods, with the data sources from the Norwegian Maritime Authority. The Norwegian Petroleum Safety Bureau analyzed the personnel factors, technical factors and organizational factors in the accident report. The results showed that the insufficient operation plan, insufficient bridge resource management, insufficient training, and communication failure were important factors that caused the collision.

Lee et al. (2017) used a descriptive model to study sinking accidents using the Accimap model. The research framework included: governance and legislation, regulatory agencies and associations, company management and local planning, technical management, operational management, and accidents. The AcciMap model was then used to investigate the Sewol Ferry accident. Finally, the research results showed that non-proactive governmental body, inadequate regulations, law oversight, poor safety culture, in consideration of human factors issues, and lack of operating standards and emergency procedures were the main reasons why such a tragedy happened.

Zhang et al. (2018) used Bayesian Network (BN) with interval probabilities to model and investigate incident reports from Marine Accident Investigation Branch UK (MAIB), Transportation Safety Board of Canada (TSB) and Australian Transport Safety Bureau (ATSB). Due to the lack of statistical information on maritime accidents, the investigation needs to include expert judgments. The authors show the differences in the input results from different experts, thereby verifying the uncertainty in risk modeling.

Kuzu et al. (2019) analyzed the risk of ship mooring operation in the maritime industry based on the mathematical model Fuzzy Fault Tree Analysis (FFTA) for maritime accident reports from MAIB (2015, 2017). The author believes that misinformation and standing in the snap-back zone during mooring operation are important basic reasons for the risk of ship mooring operation.

Hu et al. (2019) used Structural Equation Numerical Modeling to study maritime accidents. First, the HFACS model is used to manually identify the causal factors of maritime accidents, which are divided into four levels of maritime accidents, namely Unsafe Acts, Preconditions for Unsafe Acts, Unsafe Supervisions, and Organizational Influences, and structural equation model was used to simulate the path of maritime accidents. In the end, experiments showed that there were different correlations between various factors in HFACS. Resource management in the sub-hierarchy of Organizational Influences has a prominent position in the formation of the accident and has a strong correlation.

Unver et al. (2019) used a mathematical model of fuzzy fault tree analysis to study the Explosion accident of a ship and conducted expert consultation to obtain the data required for the root cause. It was finally concluded that the probability of a crankcase explosion was very low, but in terms of the lives of ships, cargo and people, a crankcase explosion is one of the most dangerous accidents in the shipping industry.

Zhang et al. (2019) used HFACS and mathematical model FTA to study ship collisions between assistantships and icebreakers on Arctic routes. The research data comes from 17 accident reports of the Swedish Accident Investigation Board and Marine Accident Investigation Branch.

It can be seen that people's research on maritime accidents is now not only seeking breakthroughs in ship hardware, but also conducting in-depth research on many factors such as operation, management, and culture. It is expected that we can try our best to ensure that the accidents are not caused by other than technological and natural disasters while controlling accidents on the ship's technical conditions.

Besides, through a literature review, the author found that a small number of articles used the Accimap and Cream models, most of which were text-descriptive causal logic diagrams. It is worth noting that in the application of the actual CREAM model, there are many changes, and the main node logic of Accimap is common in different articles. However, most of the remaining articles use the Bayesian network model. They set up corresponding nodes during the study, and the large nodes between different articles are similar, namely Organization Influence, Unsafe Supervision, Precondition, Unsafe acts. The author finds that the common model of these articles is HFACS, and most articles divide the accident occurrence process into the above four processes.

HFACS is a highly applied analysis method and has very sophisticated applications in aerospace, shipbuilding, coal mine production and other industries. At present, in the literature on human factor analysis of maritime accidents based on accident reports, almost no literature has computer-aided software involved in the automation work during the pre-processing report. Although one can use the HFACS model for quantitative practice (Akyuz and Celik 2014), Celik et al. (2010) believe that there is a lack of consistent data for analysis in the field of maritime safety. Akhtar and Utne (2015) adopted the CREAM model for the analysis of accident reports and believed that accident reports lack consistency, and it is difficult to obtain statistical data without subjective interpretation. Mazaheri et al. (2015) believe that people need a more systematic method to prepare accident reports. Zhang et al. (2019) used Bayesian networks to predict risks and believed that the involvement of different experts in modelling based on accident reports brought a high degree of epistemic uncertainty, and linguistic terms could help experts make judgments. In order to quickly process a large number of inconsistent accident data and reduce omissions in the process, the computer-aided analysis software NVivo based on natural language coding was introduced. The software is currently popular professional computer-aided qualitative analysis software, which can quantify qualitative data such as documents, videos, audios, and pictures as much as possible, process and analyze the data and draw conclusions. It can effectively store a large amount of textual data. With the help of nodes and by establishing a tree-like structure, the data with common attributes are combined to help researchers sort out the data to avoid leaks and to perform qualitative and quantitative analysis of the data.

1.3 Research content

The research content of this article mainly has the following two parts:

(1) Through a large amount of literature reading, compare the various accident cause models, and determine the use of simple and intuitive HFACS accident analysis framework for the analysis of marine accidents: through comparison, the use of data processing capabilities in statistical analysis NVivo as an analysis tool

(2) Through literature research, the author will build a comprehensive HFACS analysis framework, and use the framework to use NVivo software to plan and uniformly encode the collected maritime accidents, and to summarize the human-caused factors under the maritime accident HFACS framework. In the end, the author will put forward corresponding countermeasures to prevent maritime accidents. The technical route of this article is shown in Figure 1.

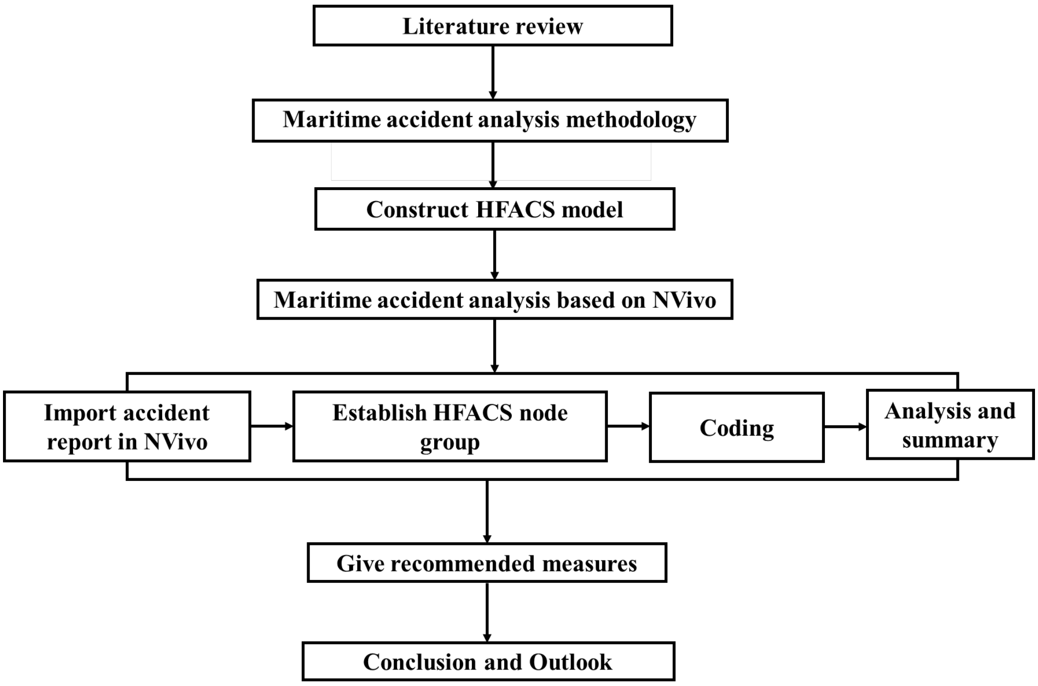

Figure 1 The research route of this article

Chapter 2 Cause analysis method and theoretical basis of maritime accidents

2.1 Qualitative analysis software NVivo and its applicability

For the processing of large amounts of information, researchers are prone to information leakage through direct reading, and the workload is huge. At this time, the use of computer-aided software has become an effective method to avoid information leakage and reduce workload.

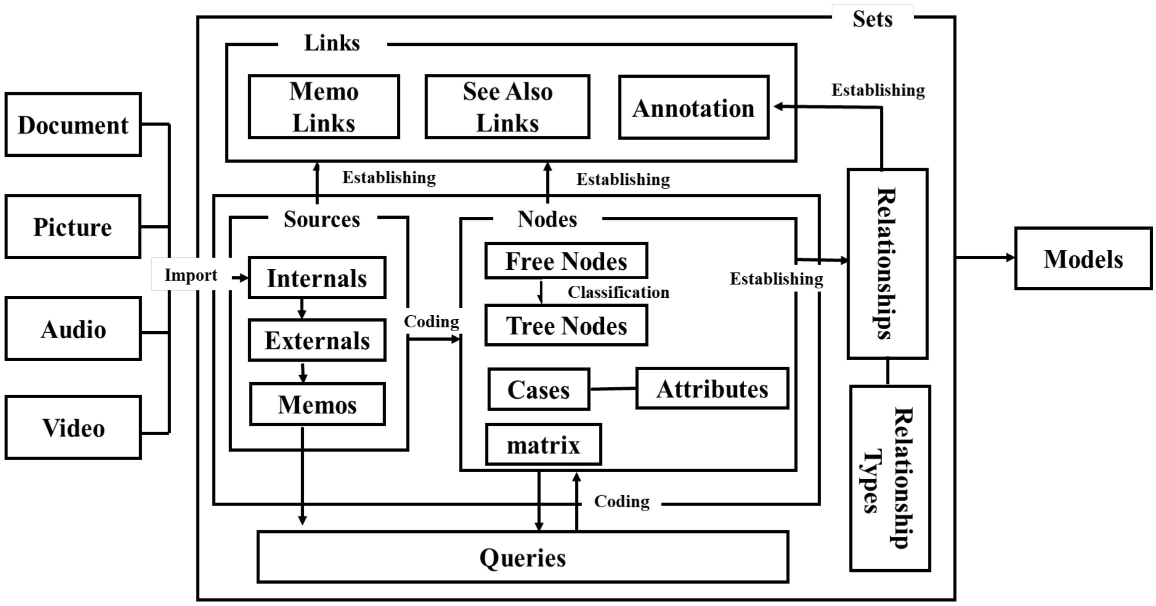

Figure 2 Analysis flow chart

NVivo software is a popular professional computer-aided qualitative analysis software (Welsh 2002; Zamawe 2015), which can quantify qualitative data such as documents, videos, audios, and pictures as much as possible, and process the data to conclude (Lewis 2004; Rich & Patashnick 2002; Rajab et al., 2018; Mortelmans 2019). The software highlights key points by creating projects, collecting materials, creating nodes, and simple coding; implementing queries to find patterns in the data and drawing models; visually displaying links in the data, creating charts, running reports, and other functions to help research. The author simply organizes and constructs complex information and extracts valuable information from the data, recording the research and thinking process, quickly evoking memories or subsequent analysis and looking around at the same time to help sort out ideas. NVivo software has strong applicability, and it can be combined with a variety of models to analyze problems and solve problems.

The general process of analyzing cases using NVivo software is four stages, which are the preparation stage, coding stage, qualitative analysis stage and integration stage. The preparation phase is divided into adding new data, creating original data and finishing data; the coding phase includes: creating nodes and encoding using attributes. The specific application NVivo analysis process is shown in Figure 2.

At present, the application of Chinese scholars to NVivo is mostly concentrated in the fields of sociology, pedagogy and psychology. However, some scholars in the world have used NVivo to process and analyze accident data, summarize and organize the causes of the accident, and have obtained satisfactory results, illustrating the huge role of the software in accident analysis (Goh et al., 2015; Underwood et al., 2016; Wold & Laumann 2015).

2.2 HFACS accident cause model and its application

HFACS was proposed by American scholars Dr. Douglas A. Wiegmann and Dr. Scott A. Shappell. Wiegmann and Shappell revealed six kinds of human error views based on the assumption of the nature of human errors and the causes of them. They are the cognitive point of view, the ergonomic point of view, the behavioural point of view, the aviation medical point of view, the social psychology point of view, and the organizational point of view. After analyzing the advantages and disadvantages of the above people's mistaken views, Reason (1990) established the famous "Swiss Cheese" model, namely the HFACS framework.

The Reason model is a conceptual model mentioned in the famous psychology book "Human error" by Professor James Reason of the University of Manchester. According to Reason, the accident occurs in the production process, where the interaction between system elements is problematic. This theory is often referred to as the accidental "Swiss Cheese" model (see Figure 3):

(1) Each piece of cheese represents a level, which is divided into four levels: organizational influence, unsafe supervision, the precondition of unsafe acts, and unsafe acts. Each hole in the cheese represents an error point. If the holes in the four slices of cheese are connected in a straight line so that the light can penetrate straight through, the accident will happen immediately.
(2) As long as one of the cheeses is moved so that the light can penetrate wirelessly, the accident can be avoided.
(3) Emphasize the organization's overall error prevention ability.

According to the "Swiss Cheese" model, the accident occurred under the combined action of the operator's explicit error of unsafe acts and the potential error of his organization, while previous studies generally believed that the cause of the accident was unsafe behaviour of personnel which triggers accident directly. However, the holes in the "Swiss cheese" model, i.e., the error points, were not clearly defined and did not indicate what the specific error points at each level were, so it was impossible to find these error points before the accident and make an improvement based on these error points.
In order to better use the model and reveal the factors that affect the occurrence of accidents in the entire production system, researchers and accident investigators need to study what the holes in each piece of cheese represent. Only in this way, the cause of the accident can be found more clearly in the accident investigation, to provide a reference for avoiding the same type of accident later. It may be better to detect and correct the errors before they occur to avoid them.

In order to make the "Swiss Cheese" model meet the needs of accident investigations, Wiegmann and Shappell refined the HFACS\based on the analysis of hundreds of flight accident reports caused by human factors. Initially, HFACS (figure 4) was designed for military aviation, but it also showed its effectiveness in the field of civil aviation. Subsequently, it was used in the fields of navigation, railway, coal mine and medical treatment to carry out accident analysis and investigation, and it can be traced surface behaviour to deep organizational causes, both in determining the cause of the accident and in formulating preventive measures, which is of great significance in determining the cause of an accident or formulating preventive measures.

HFACS summarized the causes of the accident at four levels proposed by the Swiss Cheese Model and concretized each level (figure 4).

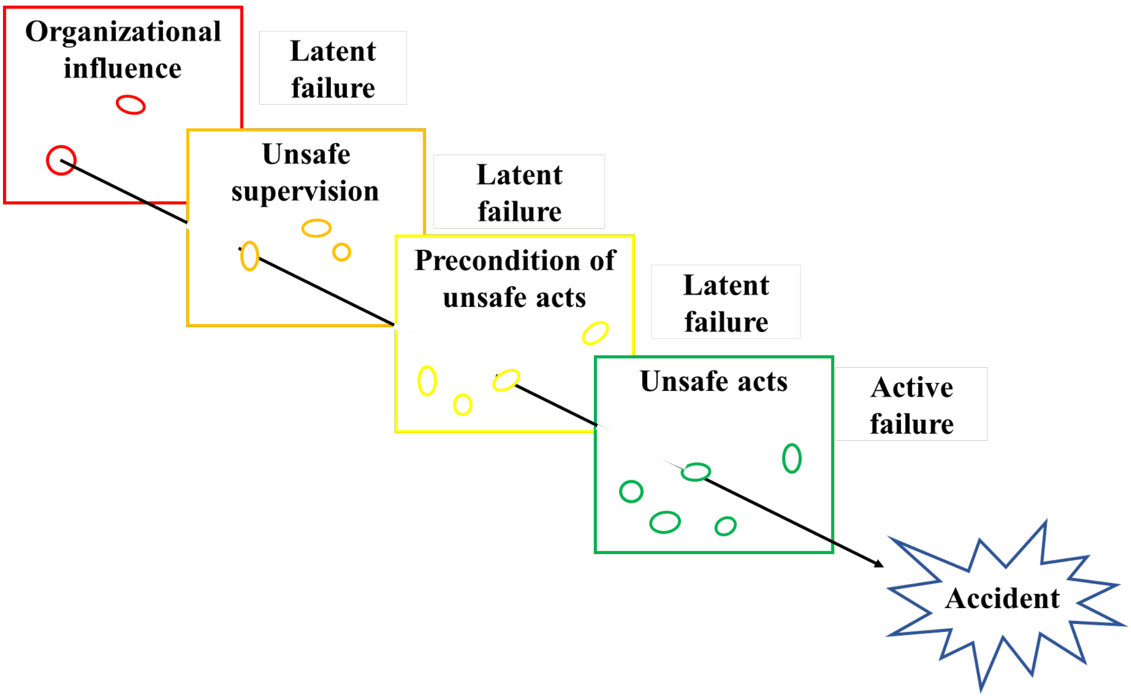

Figure 3 "Swiss cheese" model (Reason, 1990)

Human Factor Analysis and Classification System (Human Factor Analysis and Classification System) is one of the basic theories to investigate and analyze the cause of an accident. HFACS model defines the "hole" in the Reason model, analyzing human error from four levels, the first level (unsafe acts of the operator-active failure) is the level of most accident investigators concentrated. The second level (a precondition for unsafe acts-potential/active failure) addresses potential failures and more obvious active failures in the causal sequence of accidents. It also describes the operator's unqualified conditions and unqualified practices in practice. The third level (unsafe supervision-potential failure) traces the causes of unsafe behavior in the causal chain of unsafe events to the forefront supervisor. The fourth level (organizational factor-potential failure) describes the direct impact of the upper management's decision-making errors on the supervisory behavior and the behavioral premise of the operator's behavior.

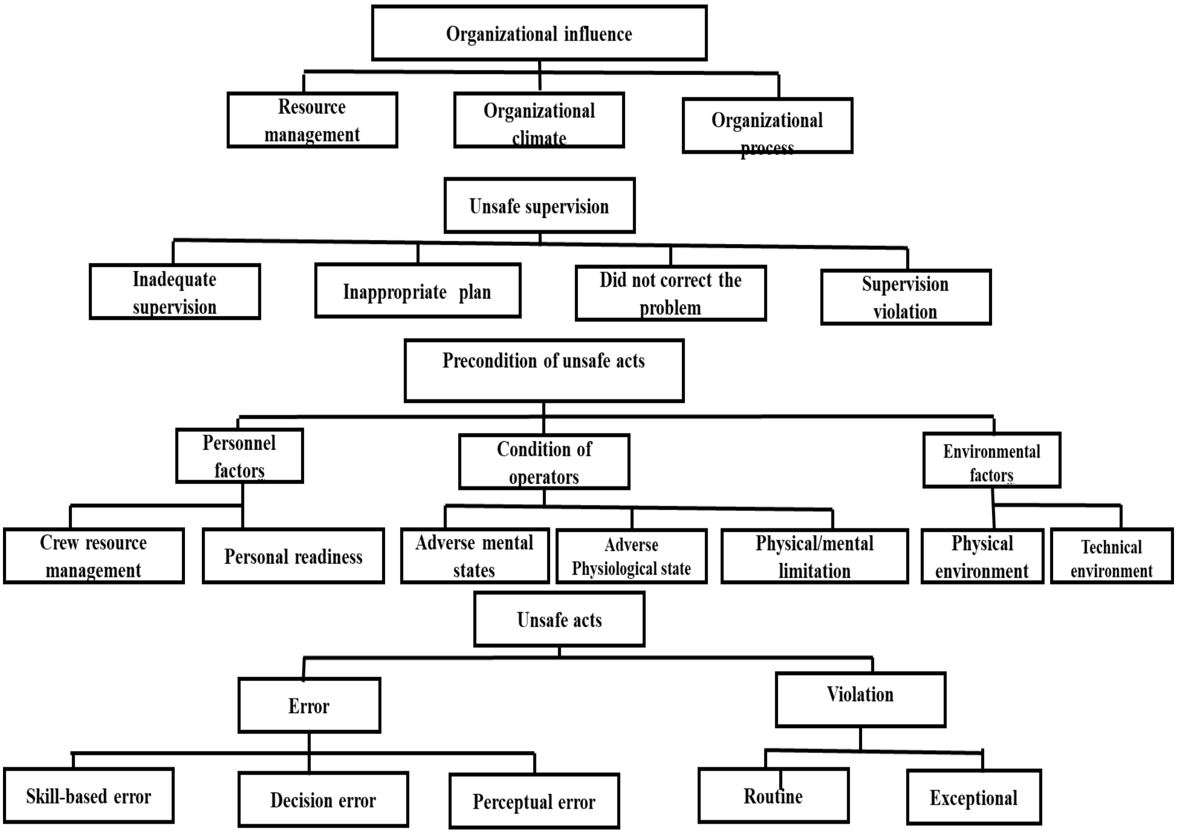

Figure 4 Flight Accident HFACS Framework

Chapter 3 Maritime Accident HFACS cause model construction

HFACS is the human cause analysis model designed with the background of aviation safety accident, in the process of applying HFACS to the analysis of maritime accident report, there will be HFACS factors and the accident cause described in the maritime accident report cannot correspond to, or its corresponding relationship has certain ambiguity, so it is necessary to determine the maritime accident HFACS model according to the characteristics of the maritime accident.

3.1 Maritime accident HFACS model

Scholars have studied the mechanism of maritime accidents for many years. Many scholars, like Chen et al. (2013) and Zhang et al. (2019), have summed up many factors, including technology, management, operation and organization. Based on previous studies and the aviation safety accident HFACS model framework, the marine accident HFACS model framework is shown in figure 5.

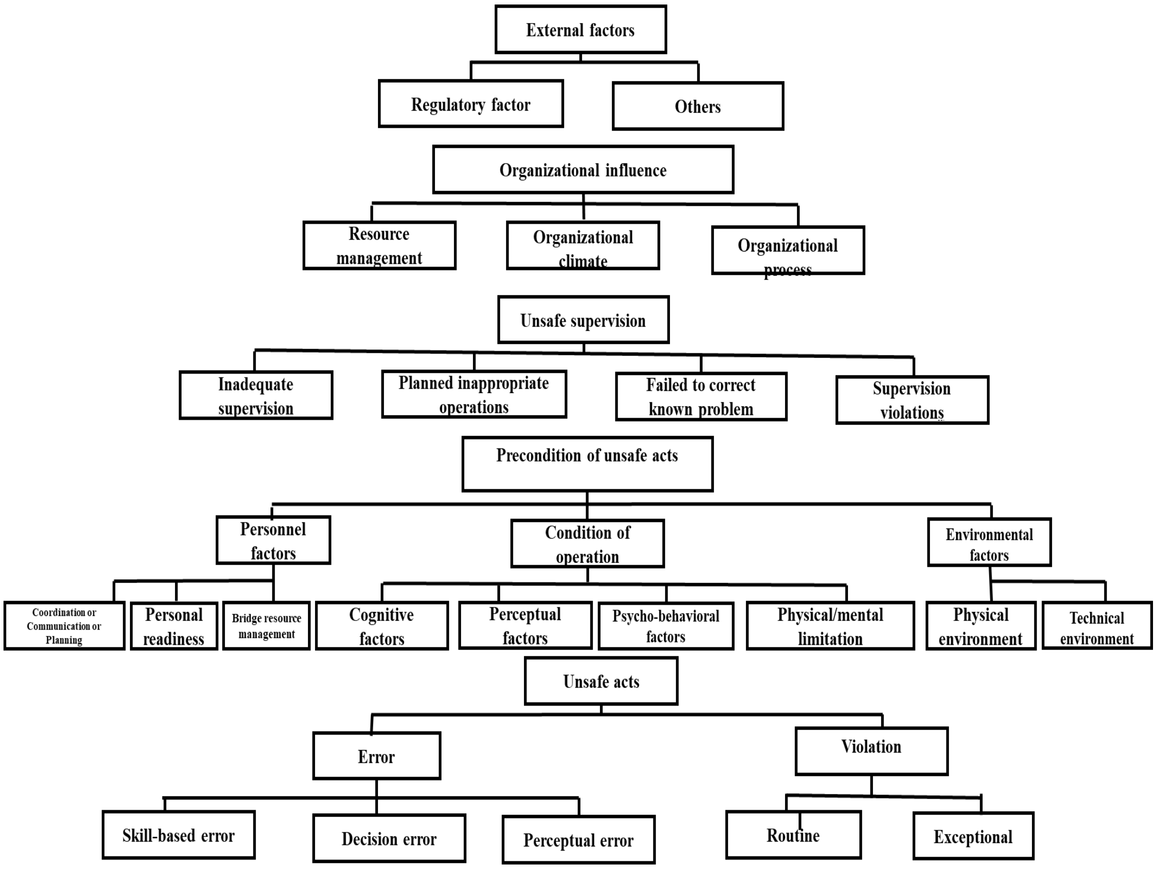

Figure 5 A model framework for maritime accident HFACS

3.2 Model operational process

The research of the scholars is very worthy of recognition and has its rationality. Therefore, according to the requirements of each element of HFACS, through the literature review on the analysis of maritime accidents, this article sets the connotation of each element in the HFACS model of maritime accidents.

3.2.1 Unsafe acts

In maritime accidents, the unsafe behaviour of the crew is often the direct cause of the accident. Combined with the HFACS model, these unsafe behaviours are two types of errors and violations; errors include three types of skills errors, decision errors and perceptual errors. There are two types of accidental violations.

Errors in maritime accidents are mainly due to unsafe operations that should not occur in the crew's skills, decision-making, and perception. Crew errors due to inattention, memory errors, and unskilled skills when performing skill operations; the main manifestations include irregular operations, brute force, blind work, risky operations, and the use of wrong methods. In terms of decision-making, due to various reasons, the crews' inadequate planning in the execution of tasks and improper assessment of the situation lead to operational errors; the main manifestations are incorrect operating procedures, improper selection of plans, handling problems beyond the ability, and insufficient experience in the face of mutations. In terms of perception, the crew is mainly visually wrong during operations such as electronic chart viewing and navigation direction judgment, resulting in inconsistency between the cognition and the actual situation. The main manifestations are instrument reading errors, direction judgment errors, altitude and distance judgment errors, etc.

The crew's violations were mainly carried out for operation progress and operation convenience. Some violations can be tolerated by the supervisors, and they are used to natural, while some cannot be approved by the supervisors, and many of such violations are too late to prevent and cause uncorrectable errors, including serious violations of operations and failure to implement safety technical measures.

3.2.2 Precondition for unsafe acts

The reasons why crew members have unsafe acts during operation are mainly due to the following three types of prerequisites, namely personnel factors, conditions of operation and environmental factors. Personnel factors include coordination or communication or planning, bridge resource management and personal readiness; conditions of operation include cognitive factors, perceptual factors, psycho-behavioural factors, and physical/mental limitations; environmental factors include physical and technical environments.

In maritime accidents, the problem of crew resource management leads to unsafe behaviour mainly manifested in the communication and coordination between the crew and the crew, such as the lack of crew teamwork, poor communication of information, and the lack of leadership skills of leaders. Among the personnel factors, the personal preparation status mainly refers to the insufficient skills, energy preparation of the operator at work. The main manifestations are failure to comply with rest regulations, lack of training, and poor eating habits.

Unsafe behaviour has a great relationship with the condition of operation, including cognitive factors, perceptual factors, psycho-behavioural factors, and physical/mental limitations. Cognitive factors refer to the crew's ability to think, Reason and remember, such as mental fatigue, anxiety, and loss of situational awareness. Perceptual factors refer to immediate sensory experience, listening, and observation capabilities are insufficient to perform tasks, such as pathological or physiological conditions that hinder safe operation, hallucinations, deviations in direction, or cold. Psycho-behavioural factors refer specifically to the crew's psychological factors that lead to unsafe behaviours, such as revenge and depression. Physical/mental limitation refers to a person's inherently limited range of capabilities in terms of body and intelligence, which is not suitable for operation.

When the crew operates the ship, their physical and technical environment will also affect their behaviour. The physical environment mainly refers to the environment of the operator's workplace, such as the bad or sudden stratum conditions of the workplace, poor lighting, noise, vibration, toxic and harmful gases, dust, etc. These environmental factors will affect the judgment of the operator, making the operator very prone to incorrect operation. The technical environment mainly refers to the situation of the equipment operated by the operator, such as no safety protection equipment or poor quality of safety protection equipment, unreasonable control design, no monitoring test equipment or equipment of poor quality, poor operation of equipment or poor maintenance.

3.2.3 Unsafe Supervision

Unsafe behaviour and its prerequisites can be found in on-site supervision. If handled promptly, unsafe behaviour may not occur, or unsafe behaviour will not lead to blowout accidents. According to the HFACS accident model framework, the factors leading to the occurrence of maritime accidents during on-site supervision mainly include inadequate supervision, planned inappropriate operations, failed to correct known problem and supervision violations.

Inadequate supervision of the crew's worksite means that the supervisor does not carry out proper supervision and guidance, such as inadequate safety education, inadequate supervision and management, low professional quality of the supervisor, and lack of attention to safety management.

Planned inappropriate operations refer to the improper work plan formulated by the senior crew, which leads to the disorderly work of the crew, such as improper crew coordination, heavy workload, and lack of rest time for the staff. It is classified as a supervision factor because it is a problem that often occurs in the supervision content.

Failure to correct problems during the supervision process is very serious and can directly lead to the occurrence of unsafe behaviours or accidents. It mainly refers to the failure of the supervisor to discover individual people, equipment, environment or other safety-related problems and behaviours. For example, the supervisor did not find the problem, found that the problem was not corrected, and the hidden trouble was not carefully checked.

Supervision violations in the supervision process mean that the supervisor deliberately ignores the existing rules and regulations, such as the failure to implement the rules and regulations and the violation of command in the supervision process.

3.2.4 Management organizational factors

In the analysis of maritime accidents, the organization factors cannot be ignored, because people in whatever position do their daily work based on organizational structure, management regulations, management processes, etc. Therefore, organizational factors cannot be ignored. According to the HFACS accident framework, it is concluded that resource management, organizational climate and organizational process are the three main factors.

The organizational process refers to the rules and regulations for the daily management of the organization, such as imperfect safety management rules and regulations, unreasonable management processes, imperfect emergency plans, etc. The loopholes in these systems will lead to a series of operations such as no rules to follow and no supervision, and the certain preconditions or unsafe behaviour will inevitably occur for a long time, which provides the possibility of a maritime accident.

Organizational climate mainly refers to safety management structure, leadership decision-making, accident investigation, values, beliefs, attitudes and other issues, such as lack of a good safety management structure, leadership decision-making does not consider safety and employees' safety awareness. These problems are not conducive to the realization of the safety management system and are not conducive to the development of supervision work, which will certainly not provide a positive impact on the prevention of maritime accidents.

Resource management mainly refers to problems that are not conducive to safe production in terms of design, human resources, capital, facility equipment and adjustment, etc., such as lack of safety personnel, defects in facility equipment design, unqualified equipment, insufficient capital investment, etc. These problems are easy to provide conditions for the occurrence of unsafe acts, which leads to the occurrence of maritime accidents.

3.2.5 External factors

Compared with the original HFACS model, many scholars have proposed external factors in recent years. For example, Chen et al. (2013) divided the external factors into legislation gap, administrative oversight and design flaws in their published academic literature. Besides, Zhang et al. (2019) continued to add Social Factors at this level. Throughout the accident report, the author of this article found that the frequency of administration oversight, design flaws and social factors is not high or almost does not appear. Therefore, this article only lists external factors as regulatory factors and others at this level. It should be noted that Regulation factors mainly refer to loopholes in policies and regulations in certain sailing areas, and some newly issued policies by the government have not been verified, which has affected the safety of navigation.

Chapter 4 Maritime accident analysis based on NVivo

4.1 Data resource

The accident reports in this article come from multiple databases, namely the Australian Transport Safety Bureau (ATSB), Marine Accident Investigation Branch (MAIB), Marine Investigation Report from Transportation Safety Board of Canada (TSB), and Transport Accident Investigation Commission New Zealand (TAIC). A total of 330 typical maritime accidents from 1998 to 2018 were collected worldwide. The types of accidents involved in the report include but are not limited to grounding, collision, fire, explosion, capsizing. There are various ship types involved, such as fishing vessels, offshore vessels, containerships, tankers, RO-ROs, bulk carriers, etc.

Table 1- Maritime accident overview

Database (accident type)	**Counting items: Accident report**
ATSB	**82**
Explosion	7
Collision	9
Fire	24
Grounding	42
MAIB	**87**
Engine failure	1
Explosion	6
Fire	18
Grounding	62
TAIC	**58**
Flooding	1
Collision	5
Fire	20

Grounding	32
TSB	**103**
Bottom contact	1
Capsizing	1
Striking	2
Collision	3
Fire	27
Grounding	69
Total	**330**

4.2 Cause analysis of maritime accidents based on NVivo

Based on NVivo analysis, the main processes of this paper are as follows:

(1) Import the collected cases into the software and make a preliminary arrangement to facilitate the subsequent analysis.

(2) The maritime accident HFACS model is established as the analysis node of NVivo, and the node is established in the software.

(3) Based on the established node, the model of each element is output through the function of the NVivo model, and the relationship between each element and its content is displayed.

(4) Case-by-case coding analysis using established nodes.

(5) Output the coded results of the case, such as charts.

4.2.1 NVivo Maritime Accident Data Processing

NVivo provides users with ways to import documents, pictures, audio, video and other materials. The accident cases used in this article are document materials. After careful study of the report, the author of this article found that more than 95% of the accident reports have accident cause analysis. For MAIB and ATSB, the CONCLUSION sections of the report will list the causes of the accident. For TSB, the cause of the accident is listed in chapter Findings-Causes and Contributing Factors. Finally, TAIC placed the cause of the accident in the

Executive Summary chapter.

Therefore, the author of this article records the chapters related to the causes of accidents in the 330 accident cases into the Word document and saves them in the DOC format. After simple sorting, NVivo is imported as internal material for coding analysis, as shown in Figure 6.

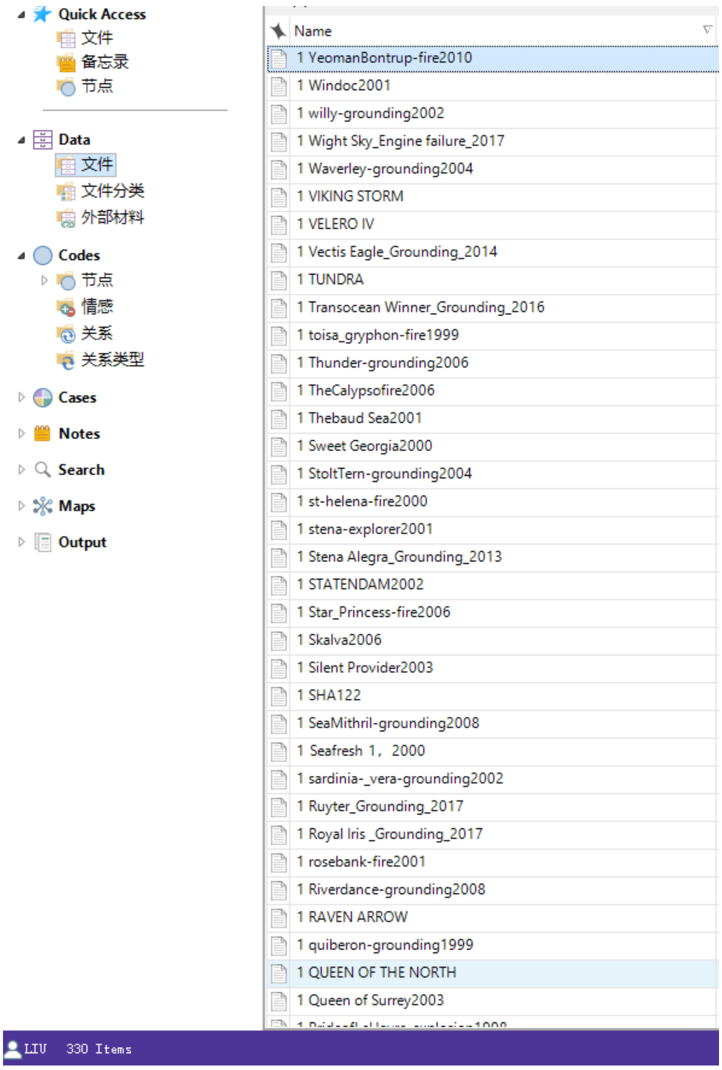

Figure 6 Introduction of maritime accident cases

4.2.2 NVivo automatic coding based on themes identification

NVivo's automatic coding function (Figure 7) can be used to capture the cause of the accident in all directions. In the end, NVivo automatically encoded from 330 files and got 1998 nodes involving a total of 3517 references, as shown in Figure 8. Through the visualization function of NVivo (Figure 9), the software draws a word cloud figure according to the word frequency of the nodes. We can clearly distinguish that the words with a higher frequency are bridge, ship, master, management, fire, engine, crew, which are words closely related to maritime safety. Figure 9 shows an example of sentence-based reference point results. The left half of the picture is the automatically encoded node, and the right part is the sentence where the specific reference point is located. Table 2 shows a more detailed example of automatic coding.

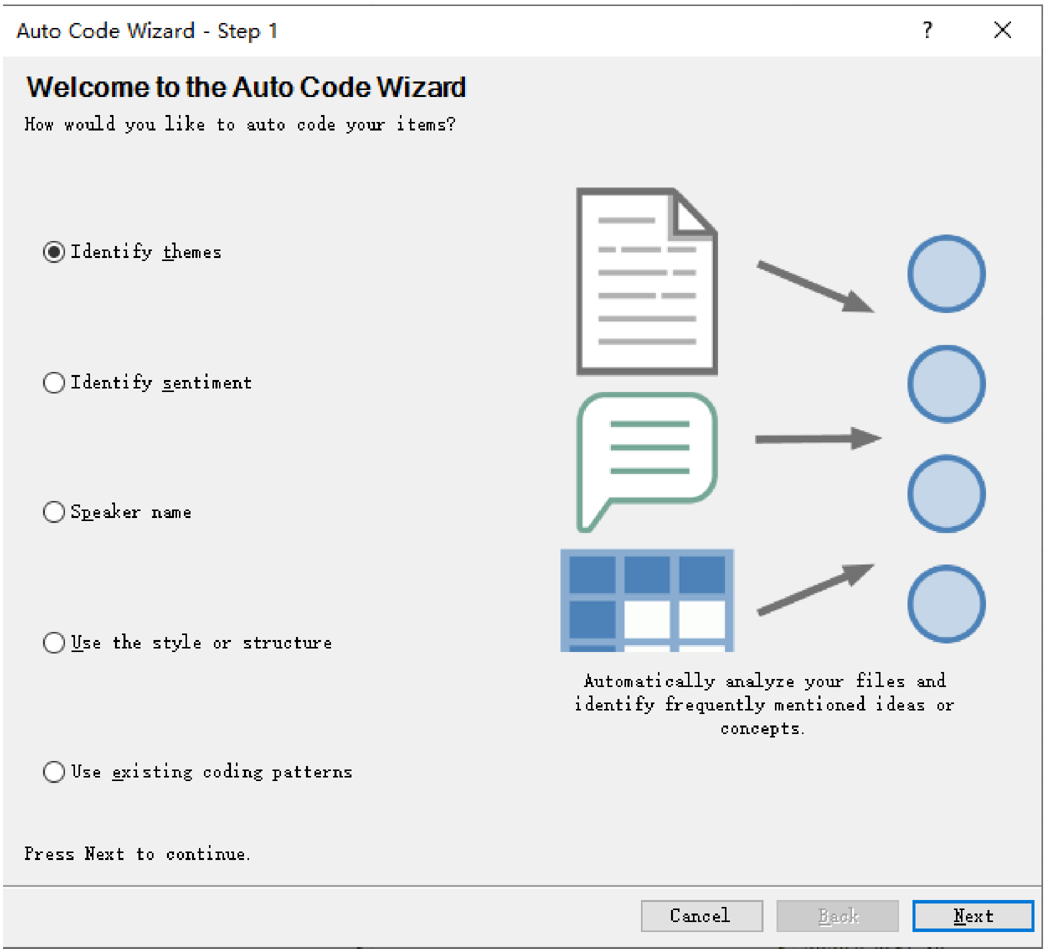

Figure 7 NVivo automatic coding function

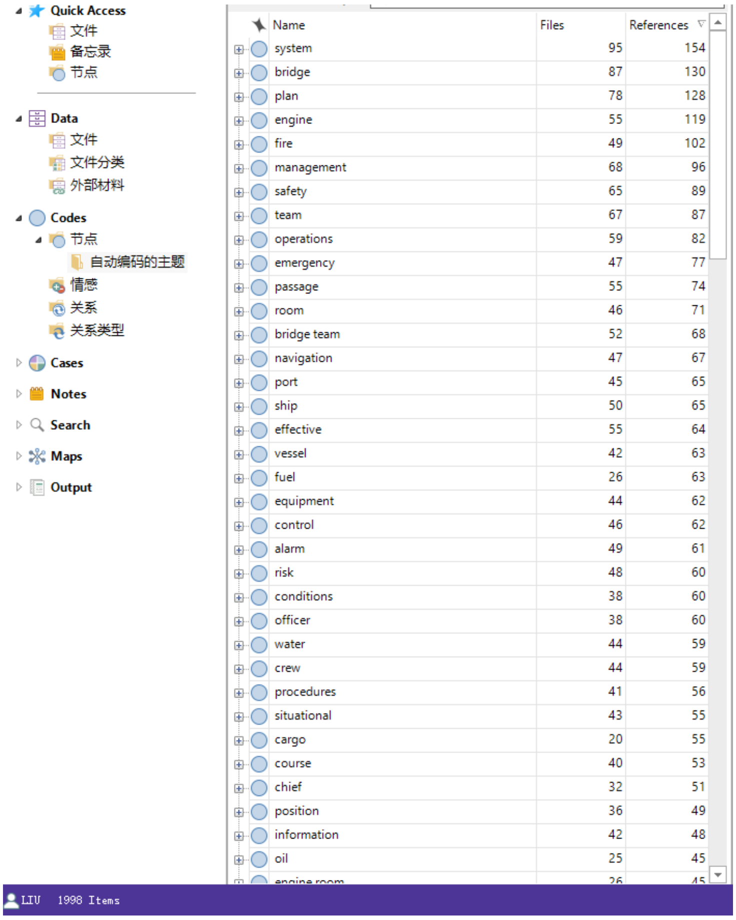

Figure 8 NVivo automatic encoding results

Figure 9 Word cloud

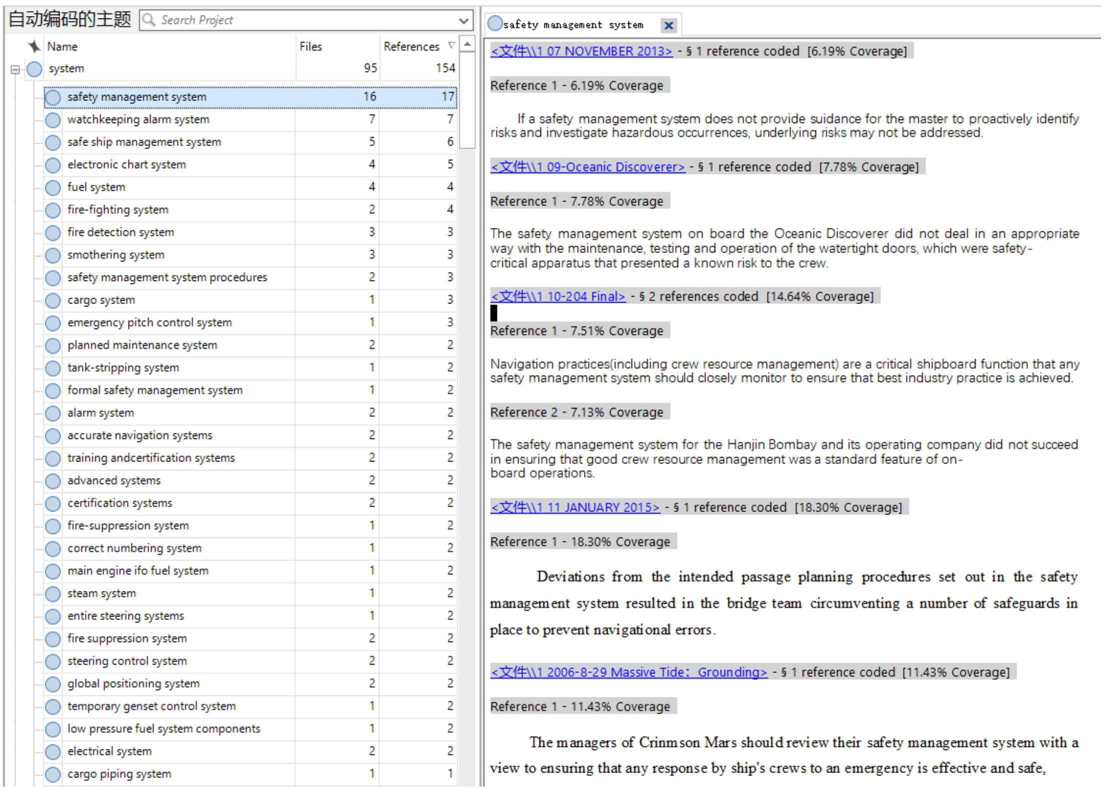

Figure 10 Encoding details

Table 2 Example of automatic coding (top four high-frequency words)

Name	Files	References	Name	Files	References
SYSTEM	95	154	**PLAN**	78	128
safety management system	16	17	passage plan	20	28
watchkeeping alarm system	7	7	contingency plan	9	9
safe ship management system	5	6	planned route	6	7
electronic chart system	4	5	planned track	4	6
fuel system	4	4	voyage plan	5	5
fire-fighting system	2	4	planned course alteration	4	5
fire detection system	3	3	original passage plan	2	4
smothering system	3	3	planned course change	2	4
safety management system procedures	2	3	**FIRE**	49	102
cargo system	1	3	fire alarm	4	4
emergency pitch control system	1	3	fire fighters	2	4
BRIDGE	87	130	emergency fire pump	2	3

bridge team	41	52	fire drill	3	3
bridge team members	6	9	fire hose	3	3
bridge resource management	7	7	local fire department	1	3
bridge watchkeepers	4	4	fire detection system	3	3
bridge team management	3	4	fire watch	3	3
bridge watch alarm	3	4			
good bridge resource management	3	3			
bridge crew	3	3			

4.2.3 Node establishment based on maritime accident HFACS model

Nodes in NVivo are a collection of topics, including free nodes, tree nodes, cases, matrices, relationships, etc. Tree-like nodes are mainly used in the research process of this article. The tree node is a node established based on the elements of the maritime accident HFACS model. First, four parent nodes of organizational management factors, unsafe supervision factors, the precondition of unsafe acts and unsafe acts are established. Then establish the relevant child nodes, as shown in Figure 11.

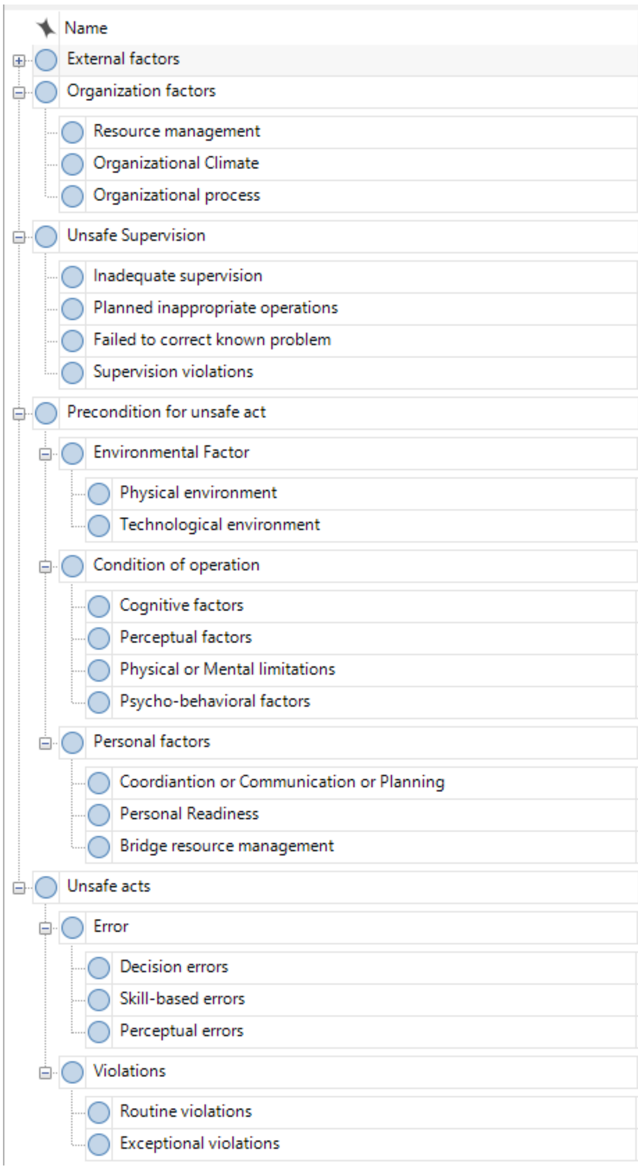

Figure 11 Establish a tree node

After establishing a tree-like node, After establishing the tree-like nodes, this article puts the 1998 nodes automatically created by NVivo into the HFACS established by the author according to the definitions of the HFACS elements mentioned in Chapter 3. Another big advantage of NVivo is reflected again, namely the automatic deletion of duplicate nodes. Because multiple nodes obtained by automatic coding may appear in the same meaning group, that is, a node in the HFACS framework and the author does not need to spend extra effort to delete the duplicate code. After putting NVivo's automatic coding into the HFACS framework, the final result is shown in Figure 12. We got a total of 1522 reference points

Name	Files	References
Precondition for unsafe act	206	601
Personal factors	178	422
Bridge resource management	159	276
Coordiantion or Communication or Plannin	98	143
Personal Readiness	1	3
Condition of operation	64	96
Cognitive factors	58	86
Psycho-behavioral factors	9	9
Perceptual factors	1	1
Physical or Mental limitations	0	0
Environmental Factor	63	83
Physical environment	47	63
Technological environment	18	20
Unsafe acts	187	393
Error	165	309
Skill-based errors	137	218
Perceptual errors	42	54
Decision errors	26	37
Violations	56	84
Exceptional violations	49	62
Routine violations	16	22
Unsafe Supervision	169	320
Planned inappropriate operations	112	171
Inadequate supervision	91	140
Supervision violations	6	6
Failed to correct known problem	3	3
Organization factors	109	174
Organizational process	84	116
Resource management	35	44
Organizational Climate	12	14
External factors	28	34

Figure 12 HFACS-based coding results

NVivo can output a visual model diagram according to the tree-like node, which can visually display the hierarchy level of each element in the HFACS model, as shown in Figure 13.

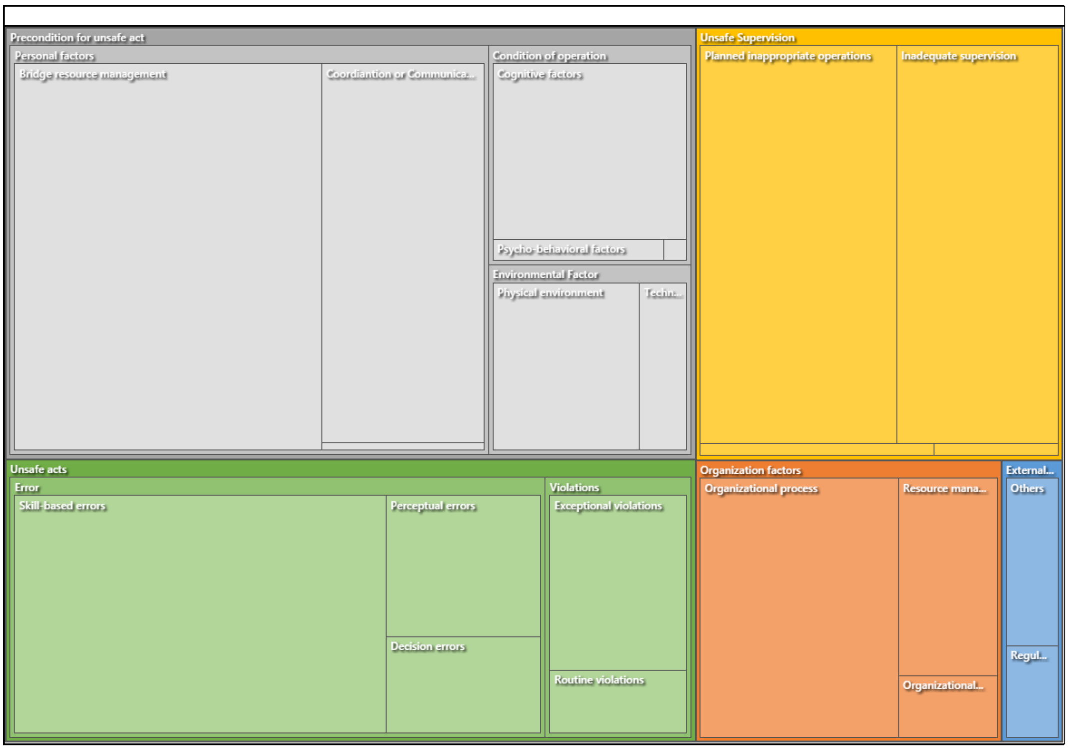

Figure 13 Hierarchy chart of nodes

In NVivo, users can choose to use various functions such as graphs, queries, or models to present nodes that meet the query conditions, visually display the data to be analyzed, and observe the relationship between the nodes. The nodes established in Figure 11 are derived from the maritime accident HFACS model, which is the cause of the maritime accident.

4.3 Definition of maritime accident case attributes

When reading and sorting the maritime accident report, the author of this article defined the attributes of each case in NVivo. The purpose is to analyze the report classification below. The details are shown in Figure 14, and the attributes set for all reports in this article include accident type, year, database, ship type, flag, etc.

	A : Type of accident	B : Year	C : Database	D : Type of ship	E : Location	F : Flag of ship
1 : 1 _H.M. GRIFFITH_1995	Fire	1995	TSB	Bulk carrier	the Stelco Hilton Work	Canada
2 : 1 _Western Viking_1997	Fire	1997	TSB	Fishing Vessel	Ucluelet, British Colu	Canada
3 : 1 03 APRIL 2015	Grounding	2015	TSB	Bulk carrier	the Pointe Fortier anc	Canada
4 : 1 1998-11-18 Britoil 22: Gro...	Grounding	1998	ATSB	Offshore vessel	the coast of Western A	Singapore
5 : 1 2 AUGUST 1998	Grounding	1998	TSB	Bulk carrier	the Port of Québec	Panama
6 : 1 2010-2-16 River Embley: Fire	Fire	2010	ATSB	Bulk carrier	Gladstone, Queensland	Australia
7 : 1 _H.M. GRIFFITH_1995	Fire	1995	TSB	Bulk carrier	the Stelco Hilton Work	Canada
8 : 1 _PETROLAB_1997	Fire	1997	TSB	Tanker	the Government Wharf a	Canada
9 : 1 _RALI II_1994	Fire	1994	TSB	Fishing Vessel	east of Cape Breton Is	Canada
10 : 1 _THERESA S_1996	Fire	1996	TSB	Fishing Vessel	Bella Coola harbour	Canada
11 : 1 _Western Viking_1997	Fire	1997	TSB	Fishing Vessel	Ucluelet, British Colu	Canada
12 : 1 00-209 La Nina	Grounding	2000	TAIC	Fishing Vessel	a bay on Rakitu Island	NewZealand
13 : 1 01 October 2016	Grounding	2016	TSB	Passenger vessel	Tofino, British Columb	Canada
14 : 1 01-205Spirit of Enterprise	Collision	2001	TAIC	Containership	Otago Harbour	NewZealand
15 : 1 01-212 Hans	Grounding	2001	TAIC	Fishing Vessel	West Head at the entra	NewZealand
16 : 1 02 March 2016	Grounding	2016	TSB	Tug	Victoria, British Colu	Canada
17 : 1 03 APRIL 2015	Grounding	2015	TSB	Bulk carrier	the Pointe Fortier anc	Canada
18 : 1 03 MAY 2003	Grounding	2003	TSB	Fishing Vessel	Portuguese Cove.	Japan
19 : 1 03 OCTOBER 2000	Grounding	2000	TSB	Tug	south of Liverpool Bay	Canada
20 : 1 0309Maersk Honam	Fire	2018	Lloy 's	Containership	Arabian Gulf	Singapore
21 : 1 03-209Mako	Collision	2003	TAIC	Containership	Tasman Bay	Malaysia
22 : 1 03-Solander Kariqa	Fire	2003	TAIC	Fishing Vessel	west of Suva, Fiji	NewZealand
23 : 1 04 MAY 2012	Grounding	2012	TSB	Fishing Vessel	Off Cape Beale, Vancou	Canada
24 : 1 04-202	Grounding	2004	TAIC	Passenger vessel	Lake Wakatipu	NewZealand
25 : 1 04-204	Grounding	2004	TAIC	Passenger vessel	Lake Manapouri	NewZealand
26 : 1 04-204 Freedom III	Grounding	2004	TAIC	Passenger vessel	Lake Manapouri	NewZealand
27 : 1 04-205	Grounding	2004	TAIC	Fishing Vessel	Steep Head, Banks Peni	NewZealand
28 : 1 04-205Bronny G	Grounding	2004	TAIC	Fishing Vessel	Steep Head, Banks Peni	NewZealand
29 : 1 04-207	Grounding	2004	TAIC	Fishing Vessel	north of Manukau Harbo	NewZealand
30 : 1 04-207Poseidon	Grounding	2004	TAIC	Fishing Vessel	north of Manukau Harbo	NewZealand
31 : 1 04-209	Collision	2004	TAIC	Fishing Vessel	entrance to the Port o	Panama
32 : 1 04-209 Joanne	Collision	2004	TAIC	Fishing Vessel	entrance to the Port o	Panama
33 : 1 04-214	Grounding	2004	TAIC	Passenger vessel	Tory Channel	NewZealand
34 : 1 04-215	Grounding	2004	TAIC	Passenger vessel	Charles Sound	NewZealand
35 : 1 04-215 Southern Winds	Grounding	2004	TAIC	Passenger vessel	Charles Sound	NewZealand
36 : 1 04-219	Grounding	2004	TAIC	Passenger vessel	Cape Brett	NewZealand
37 : 1 0421Sagar Bhushan	Fire	2018	Lloy 's	Drill ship	Arabian Gulf	India
38 : 1 04-Esprit de Mer	Fire	2004	TAIC	Passenger vessel	Milford Sound	NewZealand
39 : 1 04-San Rochelle	Fire	2004	TAIC	Fishing Vessel	about 96 nm north-nort	NewZealand
40 : 1 04-Superflyte	Fire	2004	TAIC	Passenger vessel	Motuihe Channel, Haura	NewZealand
41 : 1 05 DECEMBER 1999	Grounding	1999	TSB	Dry Bulk Carrier	Traverse du Nord, St.	Malta
42 : 1 05 OCTOBER 2009	Grounding	2009	TSB	Bulk carrier	Lac Saint-Louis, Quebe	HongKong
43 : 1 05-201 Doctor Hook	Collision	2005	TAIC	Passenger vessel	Motuihe Channel	NewZealand

Figure 14 Accident case attribute definition

Chapter 5 Output and analysis of maritime accident results based on NVivo

According to HFACS, the causes of maritime accidents are external factors, organization factors, unsafe supervision, the precondition for unsafe act and unsafe acts. After encoding 330 maritime accidents using NVivo, a total of 1526 reference points for various factors were obtained, that is, 1526 cause factors were analyzed in 330 maritime accidents, including 34 External factors, 174 Organization factors, 320 Unsafe Supervision, 601 Preconditions of unsafe acts, 393 Unsafe acts. It can be seen that the main influencing factors of maritime accidents are the precondition of unsafe acts, unsafe supervision and unsafe acts (Figure 15).

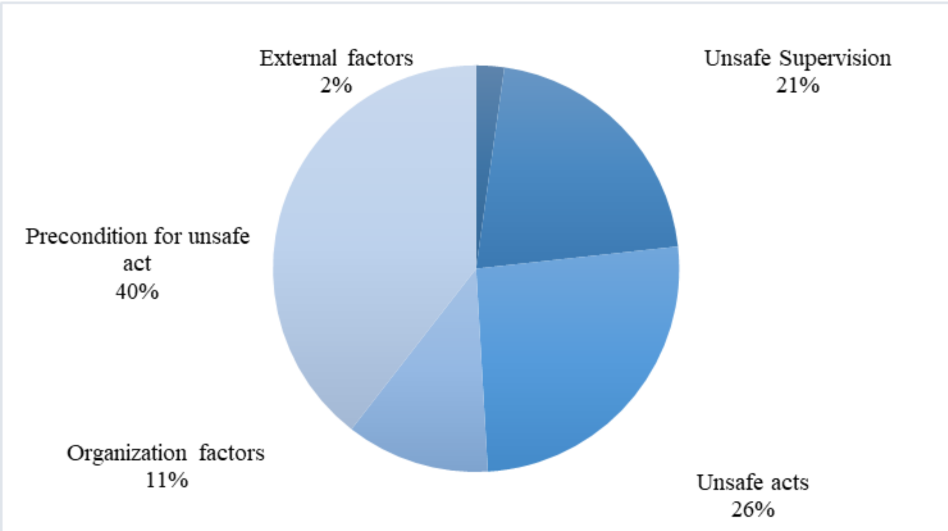

Figure 15 Maritime causal factor coding results

5.1 Analysis of external factors of maritime accidents

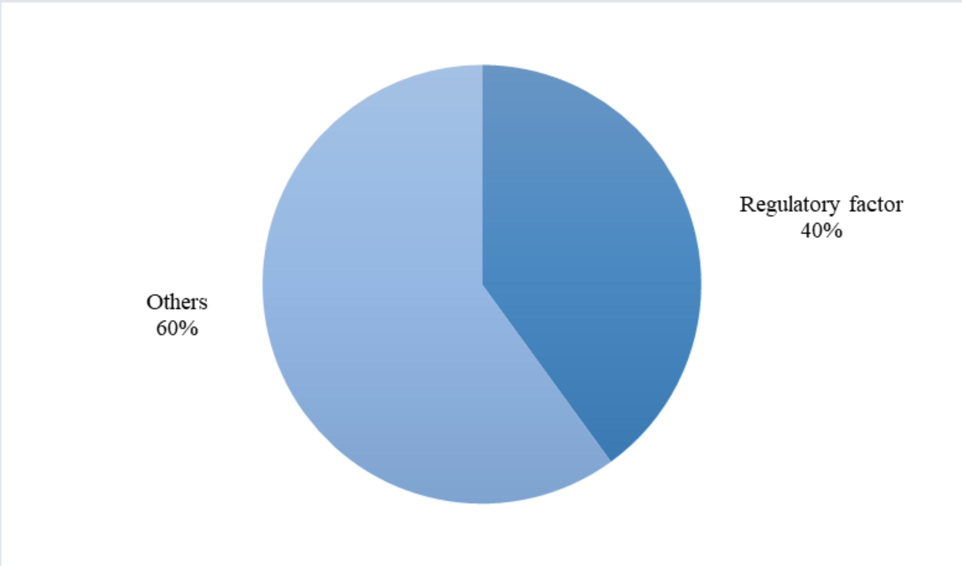

Figure 16 External factor coding results

It can be seen from Figure 16 that 40% of external factors are regulatory factors, which involve STCW and the coastal transportation policies of some countries that differ from international standards. The remaining factors mainly include the untimely release of information by the local port bureau, unprofessional fire protection departments on the shore, and inadequate training of port pilots.

5.2 Analysis of organizational factors of maritime accidents

The coding results of organizational management factors are shown in Figure 13. It can be seen from the coding result diagram that the organizational process is the most serious problem that causes maritime accidents among organizational factors. By looking at the content of the organization process vulnerabilities in NVivo, this article finds that the main problem is that the company's rules and procedures are too simple, and the security management system is full of vulnerabilities. These problems have led to the failure of the department that supplies materials to the ship, the company's safety assessment of the ship is not in place, and it may even affect the crew's unclear division of labour. Through the overall analysis of the causes of maritime accidents, we know that organizational factors are a very prominent item, so the lack of safety culture and loopholes in resource management cannot be ignored. The lack of safety culture is mainly due to the lack of safety awareness among crew members, such as alcohol management before watching; material management mainly manifests as insufficient fire-fighting equipment, insufficient navigation and alarm equipment, and insufficient qualified crew equipment, etc.

The focus is on improving the organizational process. Only by building on complete rules and regulations can we build a good safety culture and provide sufficient resources to ensure safety.

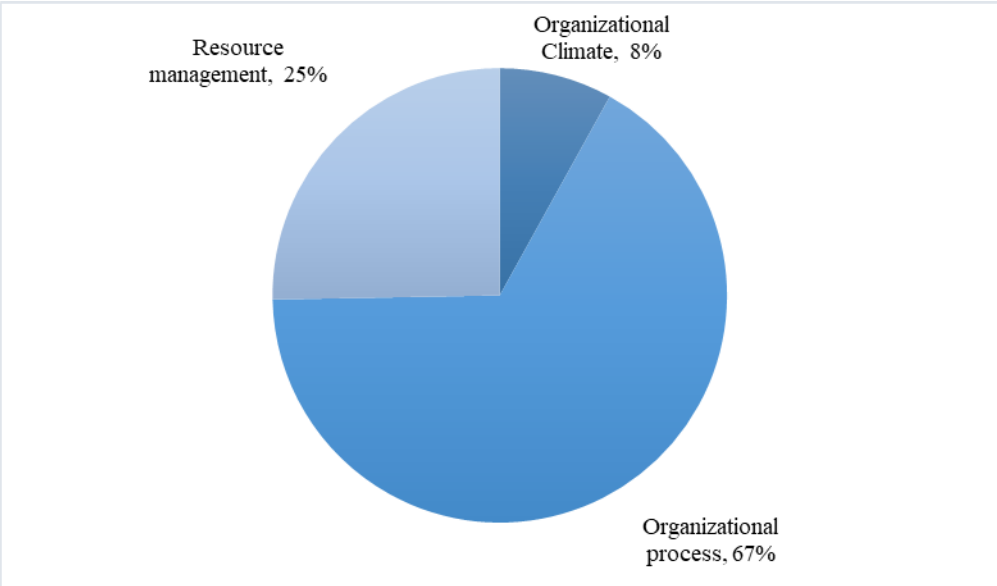

Figure 17 Organizational factor coding results

5.3 Analysis of Unsafe Supervision of Maritime Accident

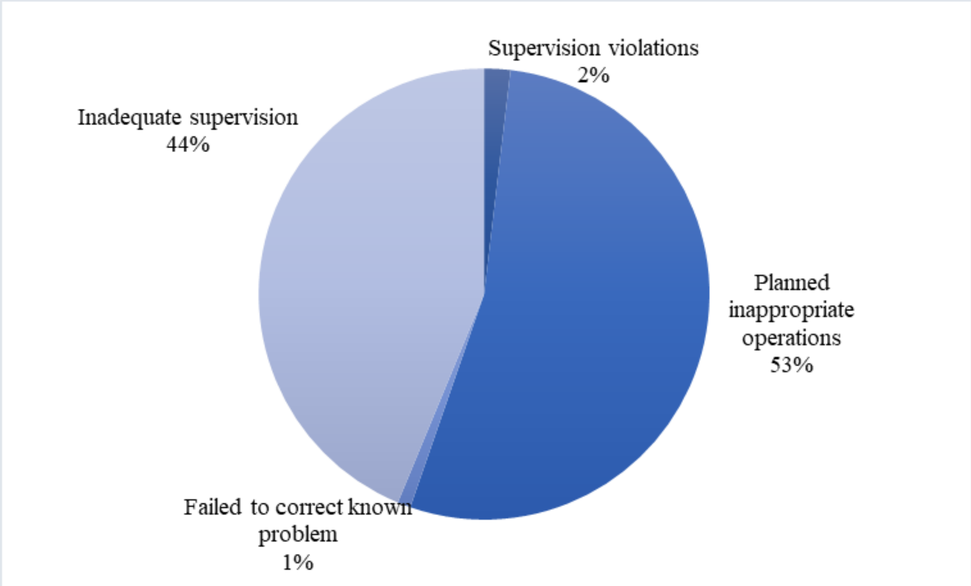

Figure 18 Unsafe Supervision coding results

The coding results of unsafe supervision are shown in Figure 18. It is not difficult to see from the coding results that planned inappropriate operations and inadequate supervision are the two most serious influencing factors of maritime accidents among unsafe supervision factors， Failed to correct known problem and supervision violation to have a relatively low probability of occurrence. It can be seen from the NVivo coding results that the main factors leading to insufficient supervision of maritime accidents are mainly insufficient oversight, lack of proper monitoring, no clear regulatory requirement. For planned improper operation, because there was no clear division of labour before sailing, and eventually, the accident occurred, the person in charge did not perform his work. Failure to correct the problem is mainly reflected in the fact that the captain has discovered that the ship's speed is too fast or other crew members have executed wrong instructions, but the captain has not corrected them.

It can be seen that during the supervision process, the quality of the supervisory personnel and the plan before the voyage have a great influence on the occurrence of marine accidents.

5.4 Analysis of Precondition of unsafe acts of maritime accidents

The precondition of unsafe acts coding results is shown in Figure 19, Figure 20, Figure 21, and Figure 22. It can be seen from Fig. 19 that the precondition of unsafe acts in maritime accidents is mainly Personal factors and bridge resource management is the most prominent in conjunction with Fig. 21, and it is mainly poor crew training results in varying qualities, bridge warning equipment to ensure navigation safety, insufficient fire extinguishing equipment, inadequate crew communication in the bridge, and insufficient human resources in the bridge. The bridge is the busiest place in maritime navigation. If the crew members in the bridge are not communicating well, or the materials, technology, equipment and personnel related to the bridge are not allocated properly, it will easily lead to accidents at sea. Besides, cooperative communication and personal readiness also play a very important role. Through reading the report, the author found that insufficient communication between the crew, including the crew between the engine room and the deck, and inadequate voyage plan are two main manifestations of this subdivision. In terms of personal readiness, the crew was exhausted by other tasks before performing the tasks, which led to insufficient personal preparation and accidents.

From the overall analysis of the causes of maritime accidents, the precondition of unsafe acts accounted for the first, so the state of the operator and personnel factors should also be paid attention to. Condition of operation is mainly manifested in cognitive factors, the main content of which is the fatigue performance of the crew, or the crew's confusion about the state of the ship.

It can be seen from the coding results that the operator's perceptual factors and physical or mental limitations involve little or no. It may be that the accident investigation does not involve this problem or does not exist. If it does not exist, it will be a good phenomenon. However, if the cause of this aspect is not investigated, it means that there are still some problems missing in these marine accident investigations.

The high frequency of cognitive factors, especially crew fatigue, is not surprising, but the psycho-behavioural factors also have a place that surprised the author. Originally, the author believed that there would be more crew depression and other similar conditions in this part, because the marine navigation environment is relatively dull and boring, though there are more and more types of entertainment facilities on board. However, after reading the coding results, the author found that there is no crew psychological depression in this part. The words are mostly due to the overconfidence of the crew members, which led to the contempt for the complicated sea conditions and, eventually, the accident. For the crew's physical and mental deficiencies and whether they are sick at work, there is little mention in the report.

Regarding environmental factors, the marine navigation environment is unpredictable. Although marine technology has become more and more developed with the progress of the times, once the key equipment fails, it will have a fatal blow to navigation safety. More common in the report are intermittent failures of navigation equipment, outdated equipment, loud noise, unclear navigation aids, and poor equipment design. The lack of maintenance is inextricably linked to human factors. The physical environment also requires us to be vigilant to it. The reports are more common in-cabin noise and bad weather. The author believes that people will design better climate navigation algorithms and cabin driving environments in the future. For the technical environment, the main Reason is that the crew relies too much on the electronic equipment, which eventually leads to an accident when the problem is too late to be corrected.

In any case, the existence of the precondition of unsafe acts provides the possibility of unsafe acts, and the facts also indicate that the precondition of unsafe acts is the most normal part of the word in the accident report. Therefore, in preventing maritime accidents, we must pay attention and pay special attention to the bridge factors.

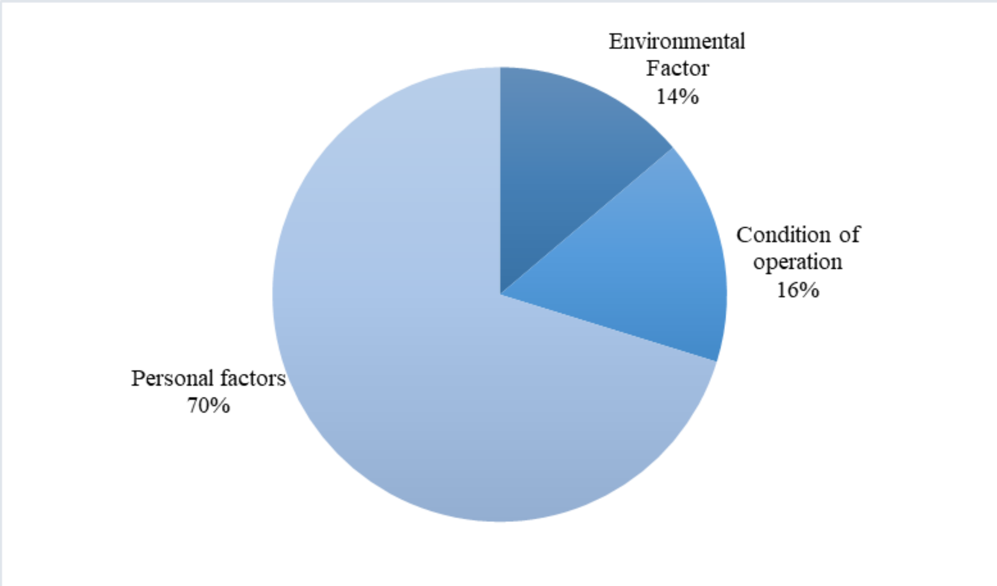

Figure 19 Precondition of unsafe acts encoding result

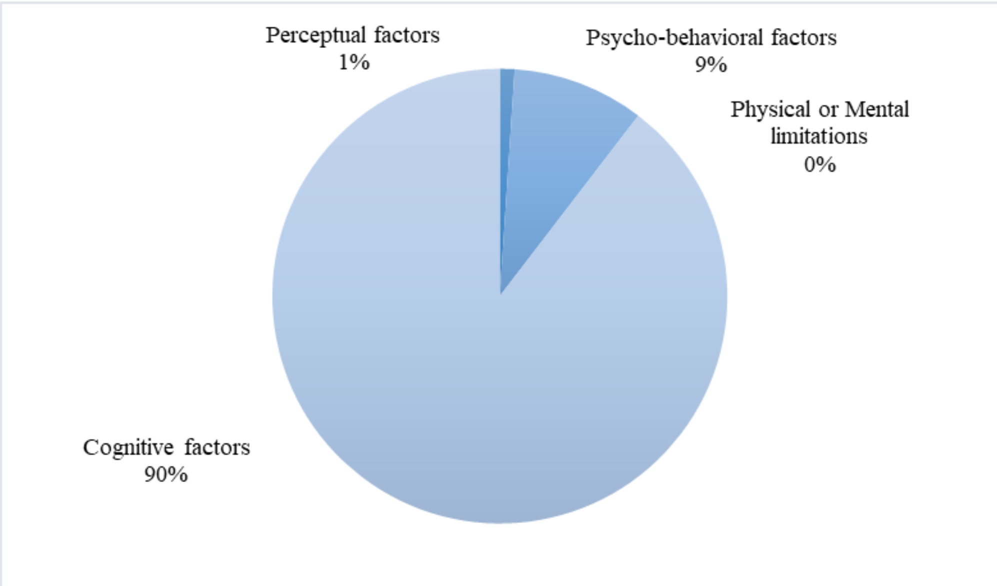

Figure 20 Condition of operation encoding results

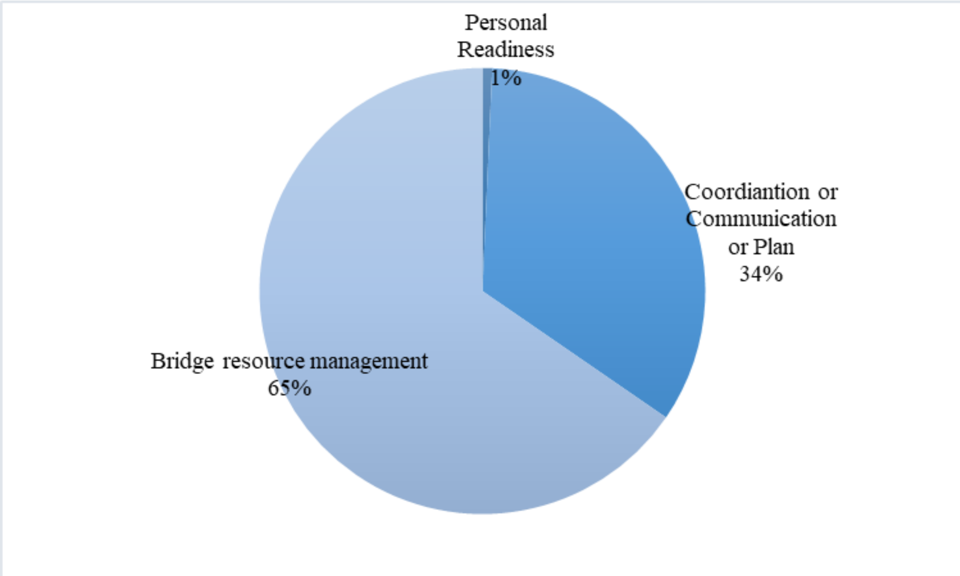

Figure 21 Personal factors encoding results

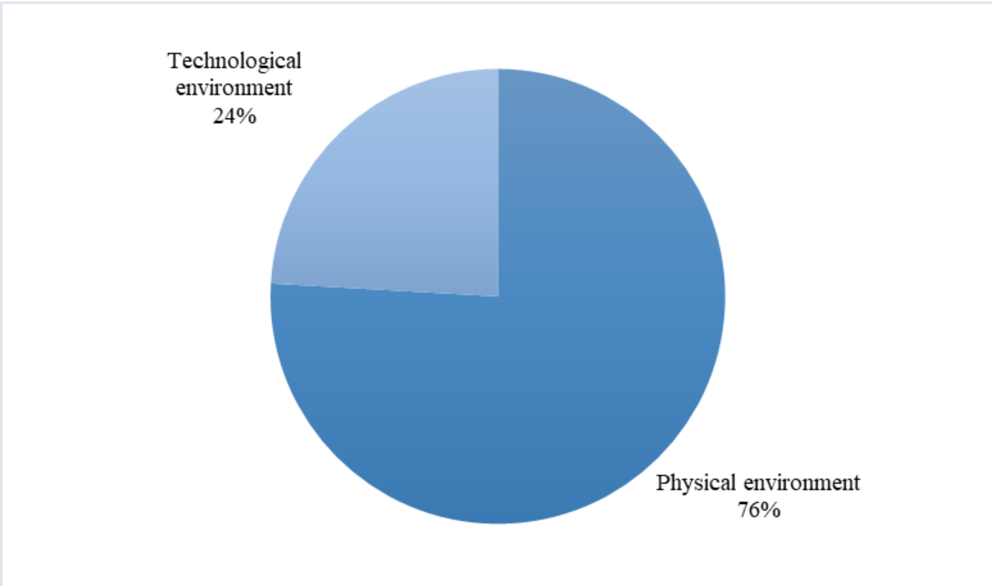

Figure 22 Environmental factors encoding results

5.4 Analysis of unsafe acts in maritime accidents

The coding results of Unsafe acts are shown in Figure 23, Figure 24 and Figure 25. It can be seen from Figure 23 that most of the unsafe behaviours in maritime accidents are errors and relatively few violations. It can be found from Fig.24 that errors mainly focus on skill-based errors, and relatively few perceptual errors and decision errors. By reviewing, it can be seen that the decision-making error is mainly manifested in the crew's underestimation of risk in the work or failure to make a clear investigation of the risk, leading to a judgment error. For example, the master's mental map of the rock did not include the underwater shape and extent of the rock; the pilot's main focus was on when the electronic bearing line (EBL) would approach Pointe Fortier rather than the exact position of the vessel; the master underestimated the risk posed by the northeasterly winds forecast for the area and chose to continue the voyage after the delay caused by the unrolling of the towing cable. Skill errors are mainly due to poor operator quality, poor skill mastery leading to operation errors, and lack of concentration leading to missed the best way to deal with problems. For example, the crew lacks understanding of the dangers of loading and unloading coal cargo; after initiating a course alteration, the chief mate focused on finding a visual reference, the Ange-Gardien range, and did not utilize the bridge navigational equipment to effectively monitor the vessel's progress as it proceeded off course and went aground; The crew did not use an echo sounder when the ship entered the shallow water.

Unsafe behaviour is usually the direct cause of the accident. Whether it is error or violation, we should take it seriously. From Figure 25, there are more exceptional violations than routine violations, which shows that exceptional violations are more likely to cause accidents. Through the inspection, it is known that the accidental violations in the maritime accident mainly include that the captain and crew did not abide by the company's drug and alcohol policies when the accident occurred; Failure to follow the navigation and duty standards and procedures set in the ship's safety management system before the accident; The captain failed to comply with STCW 95's requirements for rest time during a voyage to catch up with the schedule, resulting in crew fatigue and accidents.

Routine violations are relatively harmless and easily accepted by supervisors，For example, the implementation of the post-holding system is not carried out, and the observation is not carried out according to the prescribed number of times. Nevertheless, it is precise because of these illegal operations for a long time, which led to the occurrence of maritime accidents.

In general, unsafe behaviour can directly lead to the occurrence of maritime accidents. In the process of preventing maritime accidents, we must pay attention to the control of each unsafe behaviour, especially the control of skill-based skills.

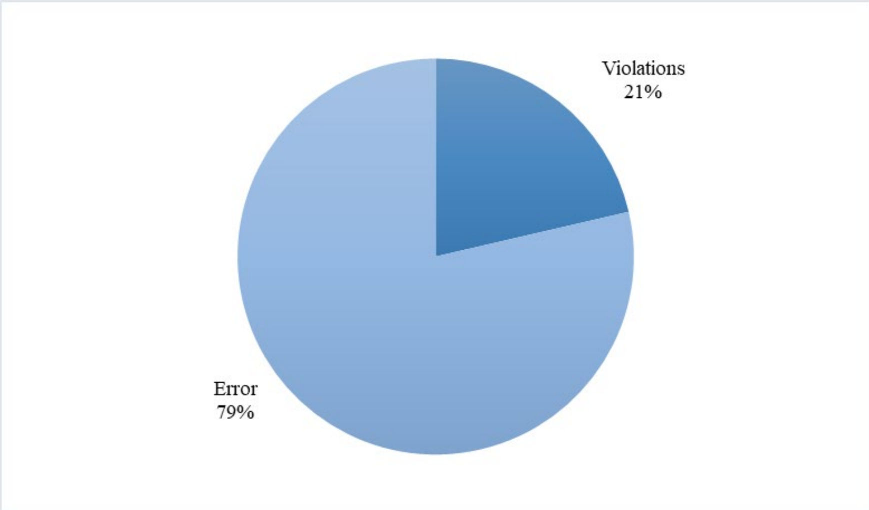

Figure 23 Unsafe acts encoding results

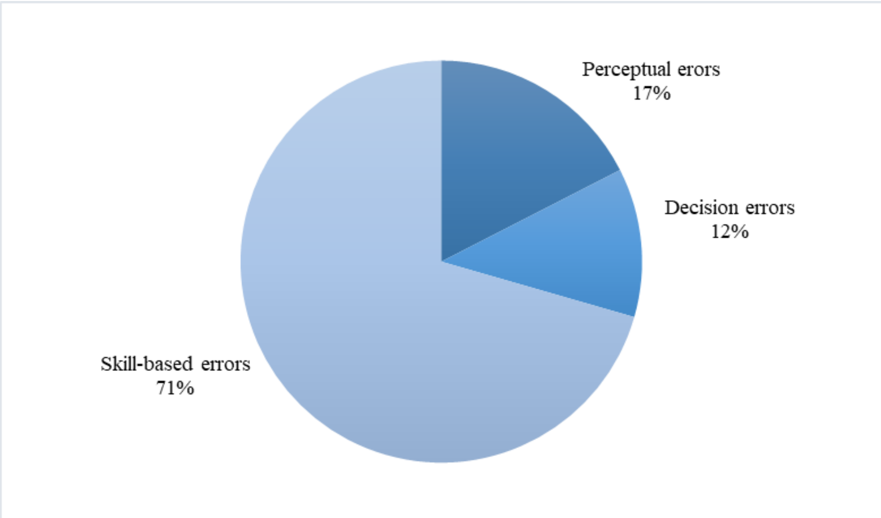

Figure 24 Error encoding results

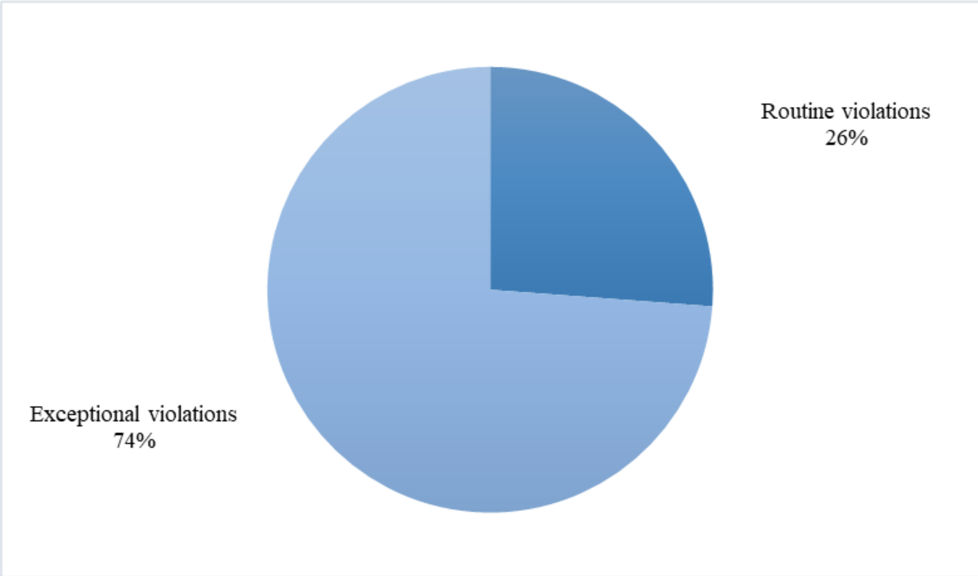

Figure 25 Violation encoding results

5.5 Human factor analysis based on different flag states

The coding results of different ship registrations are shown in Figure 26 and Figure 27.

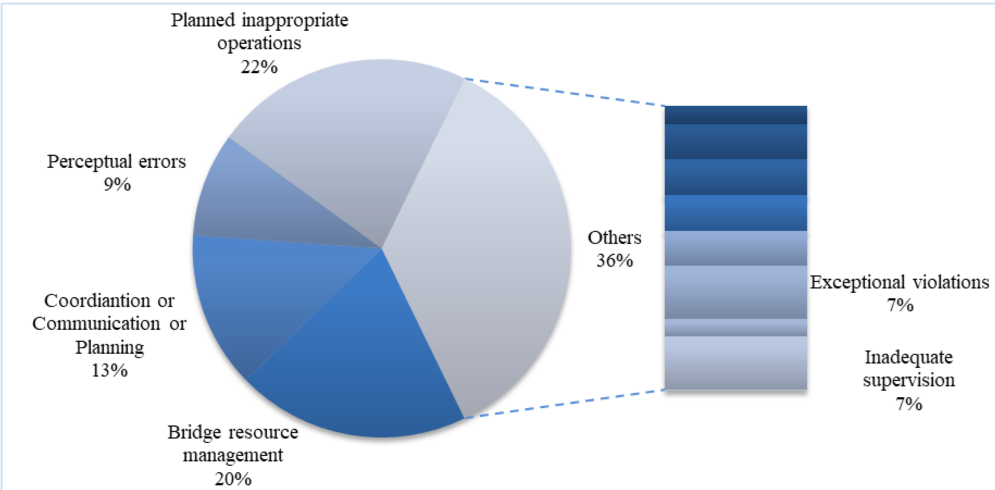

Figure 26 Coding results for Japanese, German and Greek ships

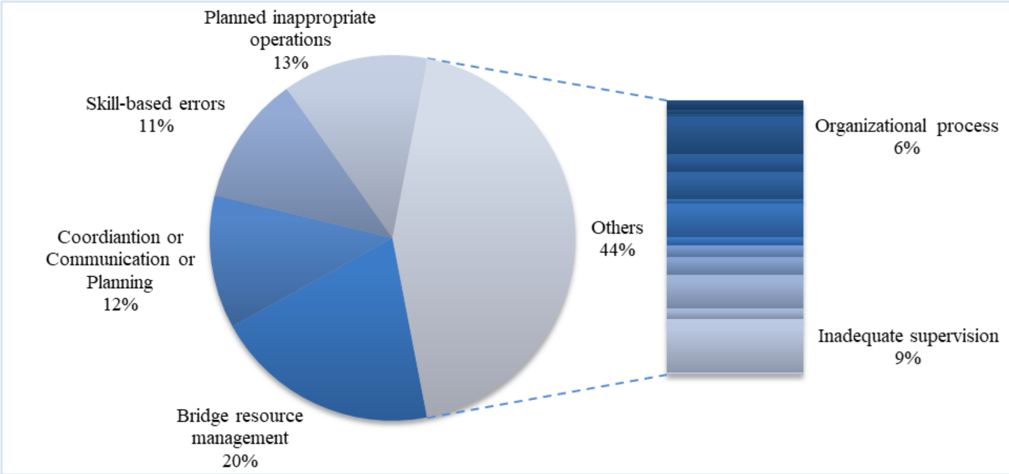

Figure 27 Coding results for the convenient flag ship

This set of pictures compares the difference between ships represented by Japan, Germany and Greece and ships with flags of convenience. It can be seen that planned inappropriate communication (or coordination or planning), bridge resource management, and inadequate supervision appear in both types of ships. However, for ships with convenience signs, their probability of skill-based error is greater than that of ships with traditional flags. This indicates that the operation level of the crew of the convenience flag ship may be lower than the crew of the traditional flag ship. However, traditional flag ships have more perceptual errors and planning errors than convenient flag ships.

5.6 Human factor analysis based on different types of ship

Figures 28 to 33 show the coding results based on different ship types. The author observed that fishing vessels have a higher probability of bridge resource management problems than other types of vessels. In particular, fishing vessels need to pay attention to physical environment problems. The supplies of fishing vessels are more scarce than other ship types. On the contrary, all ship types except passenger vessels have a higher probability of skill-based error. For all ships, inadequate supervision and poor bridge resource management are the difficulties that all ship types need to face together. It can be seen that unsafe acts supervision, bridge-related resource distribution, communication in the bridge are the topics that everyone needs to pay attention to. For RORO and tankers, including LNG and LPG, skill-based errors are the primary issue. For bulk carriers and containerships, bridge resource management is the top 1 in their common topic.

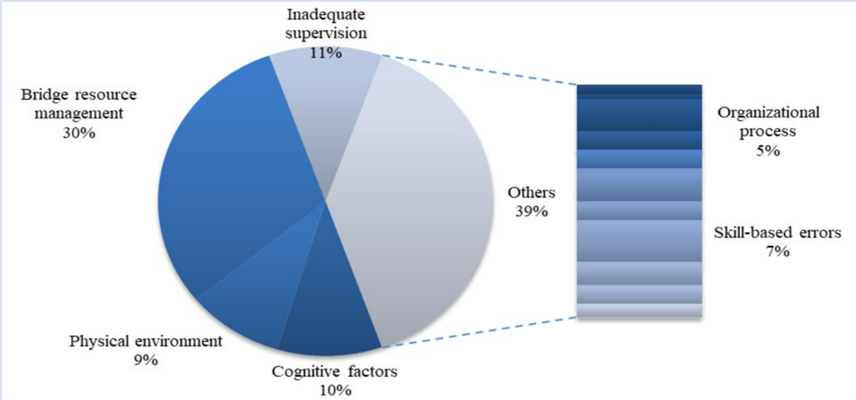

Figure 28 Coding results for fishing vessels

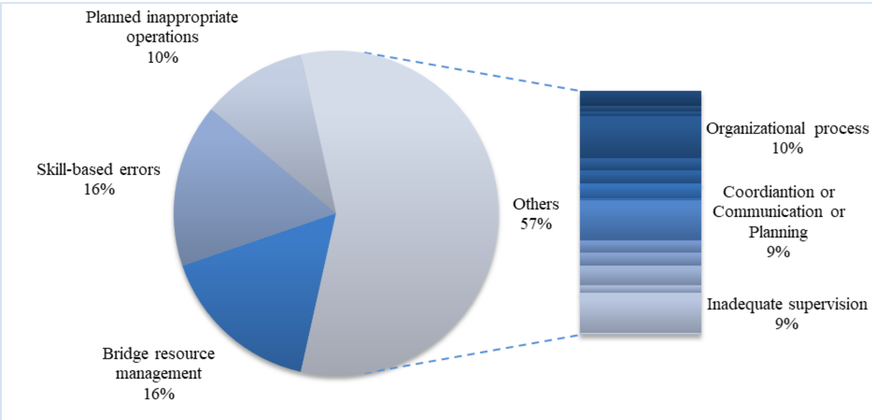

Figure 29 Coding results for tankers

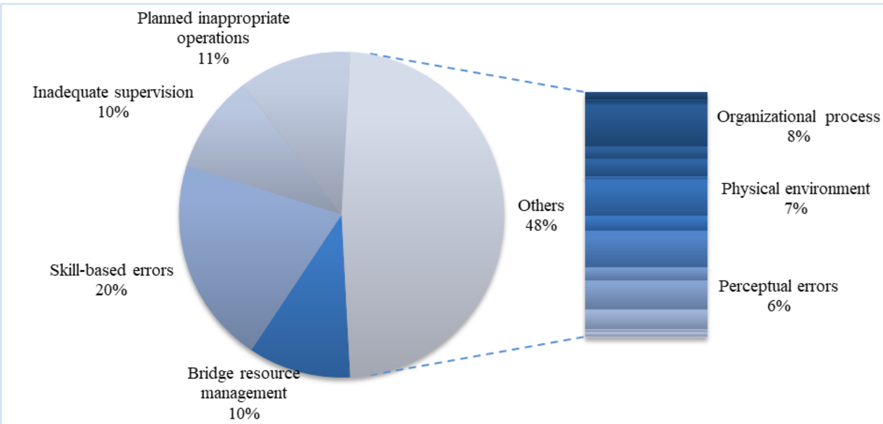

Figure 30 Coding results for passenger vessels

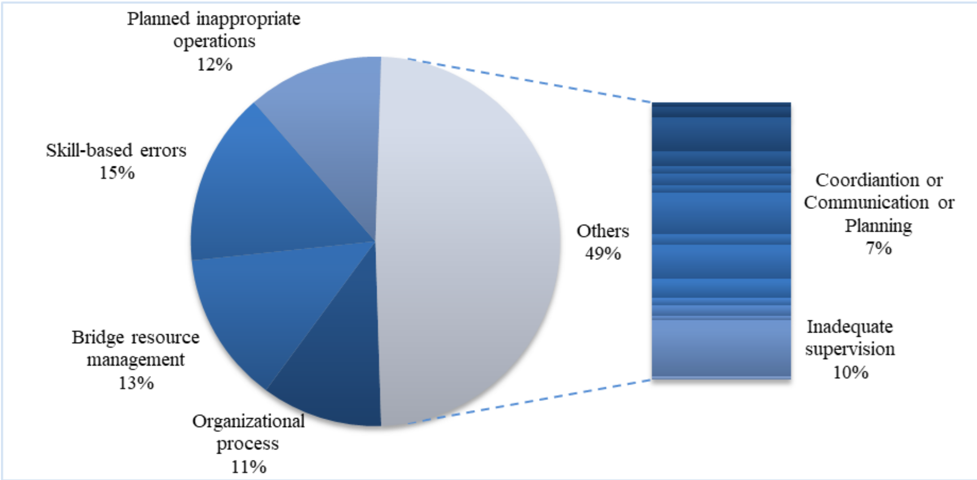

Figure 31 Coding results for RORO

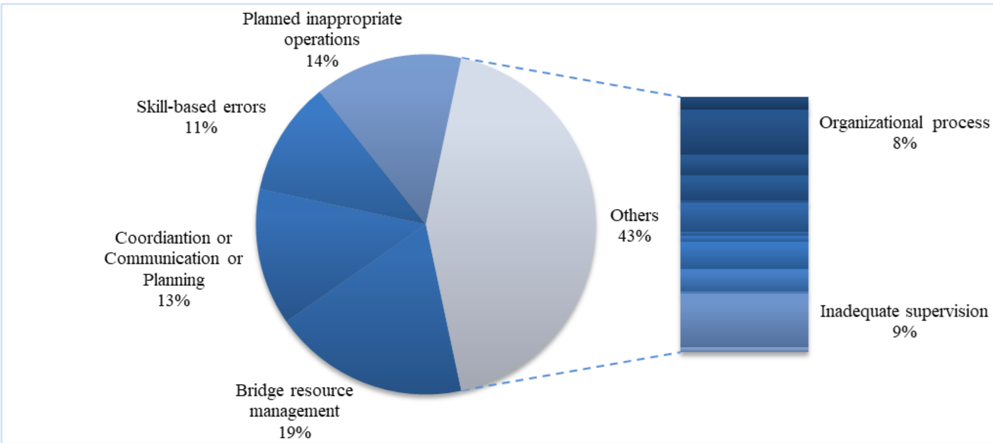

Figure 32 Coding results for bulk carriers

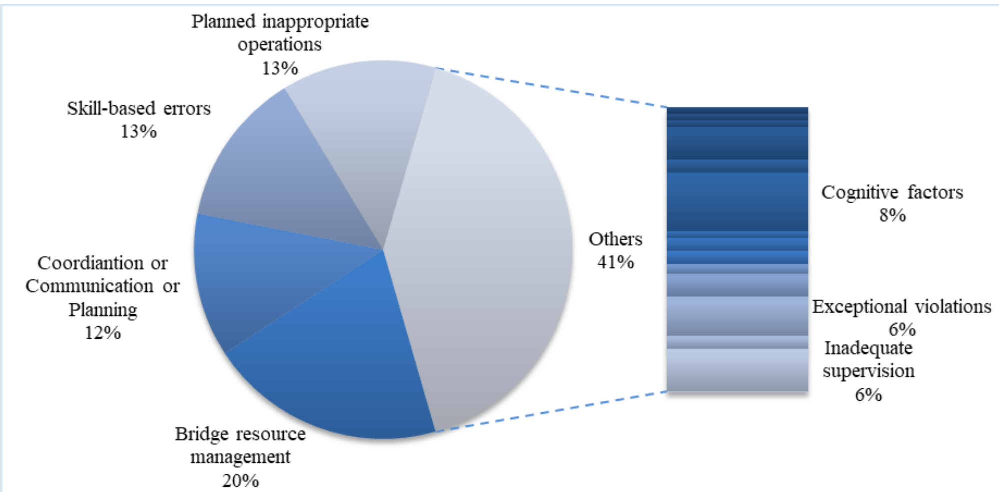

Figure 33 Coding results for containerships

5.7 Human factor analysis based on different types of accidents

Figures 34 to 36 show the coding results of different types of accidents. This section only lists the results of typical accidents, namely fire and explosion, collision, and grounding. For three types of accidents, skill-based errors and bridge resource management are their common enemies. For fires and explosions, the skill-based error is particularly prominent, mainly reflected in the inexperience of the crew's fire-fighting skills. Unlike the other two types of accidents, physical environment problem has additionally appeared in fire and explosion. It is usually due to the aging and damage of some equipment or pipelines, which eventually leads to fire and explosion. For grounding and collision, communication (or coordination or planning) factors are an increasingly serious problem, and cognitive, especially crew fatigue, can easily lead to these two types of accidents. Besides, the probability of occurrence of exceptional violation is also relatively high in collision accidents. Disasters often occur due to poor communication among crew members in the bridge, poor equipment or illegal operations.

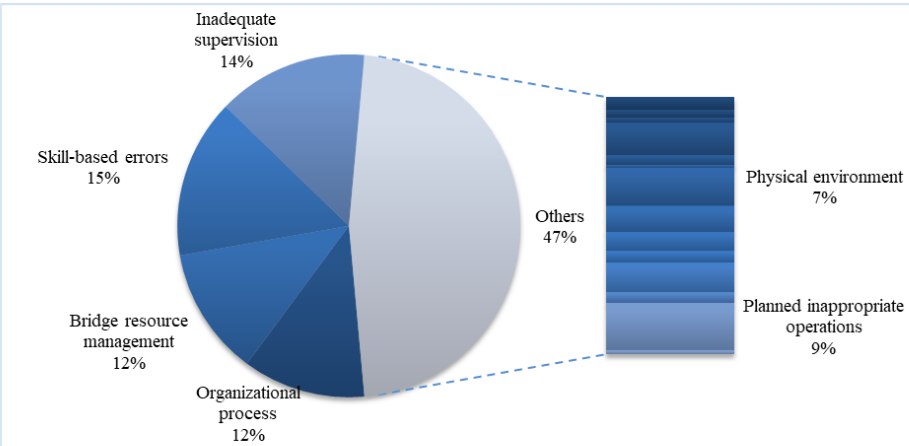

Figure 34 Coding results for fire and explosion

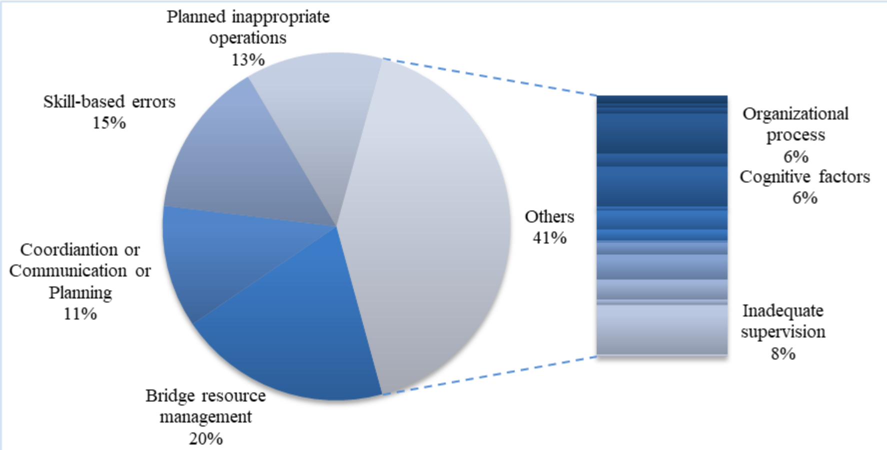

Figure 35 Coding results for grounding

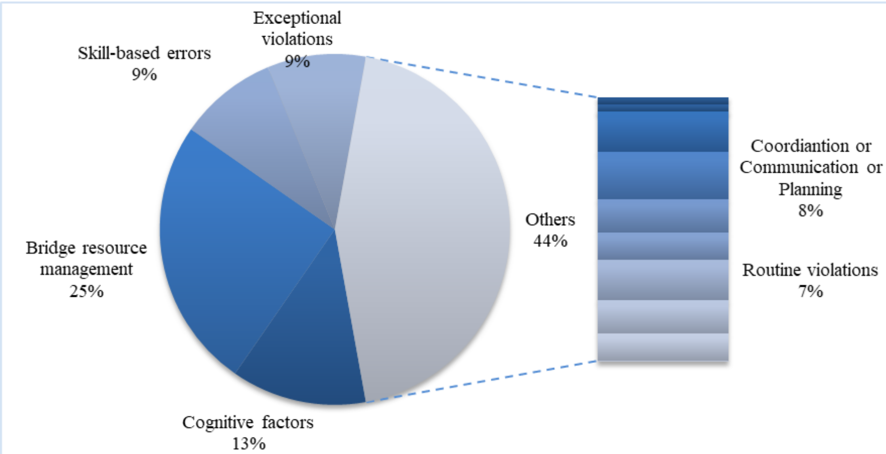

Figure 36 Coding results for collision

Chapter 6 Recommended measures for maritime accident intervention

Maritime accidents will cause not only serious ecological harm, economic losses, but also cause serious casualties, which all we are unhappy to see. Through the analysis of the causal factors of marine accidents, this article puts forward the following suggestions for intervention.

6.1 Implement organizational safety management system

From the previous analysis, the very serious organizational factor in maritime accidents is that the organizational process is not in place. Combined with the lack of supervision, it is obvious that the situation of supervision and management has a very serious impact on the implementation of policies and regulations that restrict and regulate organizational work. Supervision management is a more direct safety management measure, and it also has a large impact on the prerequisites of unsafe behaviour and unsafe behaviour.

Therefore, there are three suggestions for the intervention of maritime accidents. First, it is necessary to formulate detailed regulations on organizational work and to clarify the duties of the relevant crew in the regulations, and the implementation must be monitored. Second, it is necessary to formulate a comprehensive supervision system. This system is not only to supervise the implementation of the work regulations by the crew but also to find out whether the crew's behaviour and operation in daily navigation have hidden dangers of accidents. The site environment also needs to be supervised; Third, in order to better cooperate with the supervision and management system, this article recommends the establishment of a hidden safety inspection system, regular inspection and rectification of hidden dangers.

6.2 Improve crew working conditions

The working status of the crew has a great influence on the occurrence of maritime accidents. From the analysis of the precondition of unsafe acts in the previous chapter, it is found that the causes of maritime accidents are mostly caused by crew fatigue and poor communication among the crew working in the bridge, which results in poor strain energy for crews to handle emergencies. Therefore, mitigating crew fatigue and improving crew work efficiency are items that should be emphasized in maritime accident intervention.

Based on the above considerations, the following three suggestions are made on how to improve the working conditions of the crew. First, carry out more humane care activities, regularly ask the crew's psychological and fatigue status, and customize sensible diet and entertainment activities for the crew. Second, flexible scheduling to prevent crew members from being paralyzed by the unchangeable work schedule. Thirdly, with the help of AI technology, a fatigue warning device should be installed on the bridge, such as face recognition technology widely used in the field of automobile safety.

6.3 Strengthen the construction of safety culture

Strengthen the construction of safety culture, and the ultimate goal is to allow enterprises and crew to have a good safety climate. From the previous analysis, it can be concluded that the loopholes in safety culture are mainly employees' neglect of safety and do not care about the safety system. For the safety of maritime transportation and the avoidance of maritime accidents, the improvement of safety culture must be highly valued.

Based on the above considerations, the following three points are proposed to avoid the occurrence of maritime accidents to enhance the construction of safety culture. First, develop a safety knowledge training system for production and regularly conduct safety navigation knowledge training, including the introduction of maritime accident cases, the study of safety operation rules, and navigation technical points, etc., in order to improve the safety quality of crew members. Second, formulate a system for carrying out safety cultural activities and regularly organize safety activities, such as safety production knowledge contests, safety slogan solicitations, safety operation reward etc., to provide a safety culture climate. Third, formulate a pre-shift safety production knowledge question and answer system, and give appropriate punishment to employees who cannot know the safety knowledge of their position. In this way, we urge everyone to study and understand the knowledge of production safety earnestly.

Chapter 7 Conclusion and outlook

7.1 Conclusion

The main research conclusions of this paper are as follows:

(1) According to the literature research methods, the HFACS model framework for maritime accidents is established, and the content of each element is summarized, which provides a basis for the analysis of maritime accidents using this model.

(2) With qualitative analysis software, NVivo, 330 maritime accident reporters from ATSB, MAIB, TSB, and TAIC from 1998 to 2018 were statistically analyzed, and the causes of maritime accidents were obtained from five aspects: external factors, organizational factors, unsafe supervision, the precondition of unsafe acts and unsafe acts.

(3) Based on the analysis results, suggestions for implementing the organizational safety management system, improving the working conditions of the crew and strengthening the construction of safety culture are given to prevent maritime accidents. It is expected to contribute to the intervention of maritime accidents.

7.2 Outlook

Due to various reasons, there are the following three shortcomings, which need to be further studied and improved.

(1) Since the writing of the paper can only be done on its own, the accuracy of the coding summary for 330 reports will be higher in the case of multi-person assistance and consistency testing.

(2) Since data sources come from different databases, it is questionable whether reports from different systems can be applied uniformly.

(3) Because HFACS is only a human factor classification framework, it is impossible to simply use this framework for correlation analysis between upper and lower factors. In the future, we can continue to explore the correlation analysis between factors to draw more conclusions.

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